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U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

Increasing Energy Access in Developing Countries: The Role of Distributed Generation

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Abbreviations

BCSE	Business Council for Sustainable Energy
CNE	National Energy Commission in Chile
CHP	combined production of heat and power; often called co-generation when referring to industrial CHP
CO	carbon monoxide
CO_2	carbon dioxide
DG	distributed generation
GW	gigawatt (1 watt x 10^9)
IEA	International Energy Agency
IEEE	Institute of Electric and Electronic Engineers
kW	kilowatt (1 watt x 1,000)
kWh	kilowatt-hour
MW	megawatt (1 watt x 10^6)
MWh	megawatt-hour
NO_x	nitrogen oxides
NGO	non-governmental organization
NREL	National Renewable Energy Laboratory
OECD	Organization for Economic Co-operation and Development
PM-10	particulate matter
PV	Photovoltaic
RE	rural electrification
SO_x	sulfur oxides
SO_2	sulfur dioxide
UK	United Kingdom
U.S.	United States
USAID	U.S. Agency for International Development
WADE	The World Alliance for Decentralized Energy
\$	U.S. dollar

1. Distributed Generation in a Changing World

The massive power outages that occurred in the United States and Italy in the summer of 2003 have drawn attention to the fragility of electric transmission and distribution systems, even in the world's most advanced energy systems. Such outages are common occurrences in developing countries where the power system failures are endemic. Transmission and distribution line losses in developing countries often run as high as 20 to 30 percent due largely to inadequate maintenance and investments in distribution systems. The financial viability of electric utilities in developing countries also remains constrained by improper billing, lack of payment, unauthorized connections and continued subsidies that often benefit customers who have the ability to pay.[1]

Over 1.64 billion people worldwide (99 percent of them in developing countries) live without access to electricity. Four out of five of those are in rural areas[2] and 80 percent are from South Asia[3] and sub-Sahara Africa.[4] Even in Latin America, where total electrification is much higher at 86 percent, nearly half of those in rural areas still lack access to electricity.[5] As the International Energy Agency (IEA) *World Energy Outlook 2002* notes, the "lack of electricity exacerbates poverty and contributes to its perpetuation, as it precludes most industrial activities and the jobs they create."[6]

In an attempt to reduce energy costs, attract private capital and improve service, countries throughout Asia, Latin America and the Caribbean began opening their electricity markets to private investors in the 1990s.[7] With the introduction of competition, governments started to privatize state owned utilities, unbundle energy production and distribution and create independent regulatory bodies. However, electricity reforms in these countries have advanced slowly and unevenly and independent electricity regulators remain inherently weak.[8] Despite the advances made in Latin America and the Caribbean, for example, only 40 percent of the countries in the region have begun to privatize existing generation or distribution assets.[9] Further, many of those countries that have restructured their electricity sectors, have failed to achieve the results desired largely due to a lack of adequate competition, the poor financial state of the electricity sector, and the inability of customers to pay the contracted tariff.[10] In Brazil, the Dominican Republic and Georgia, the government has even been forced to buy back failed privatized utilities.

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1 IEA, ENERGY OUTLOOK 2002 at 384. In India one third of all of the electrical power is consumed by unauthorized connections. The figures are even higher in Kenya and other African countries. IEA, DG IN LIBERALIZED MARKETS at 113.

2 IEA, ENERGY OUTLOOK 2002 at 373.

3 South Asia is made up of Afghanistan, Bangladesh, India, Nepal, Pakistan and Sri Lanka.

4 Sub-Sahara Africa includes all of Africa except North Africa – Algeria, Egypt, Libya, Morocco and Tunisia.

5 IEA, ENERGY OUTLOOK 2002 at 377, 380 and 132.

6 *Id.* at 33.

7 Countries where restructuring is underway include Argentina, Bolivia, El Salvador, Nicaragua, the state of Orissa in India, Pakistan, the Philippines and some countries in Africa. *Id.* at 33 and Kozloff, *Electricity Sector Reform in Developing Countries*.

8 Bacon, Robert, *A Scorecard for Energy Reform* at 4. A study of 115 developing countries conducted by the World Bank in 1999 found that Latin America and the Caribbean had undertaken 71 percent of the key reforms identified by the Bank, while only 17 percent of the countries in the Middle East and North Africa and 15 percent in Sub-Sahara Africa had carried out such reforms. *Id.*

9 *Id. See also*, von der Fehr, *Power Sector Reform* at 365-366.

10 Govt. of India, *Report of the Committee on DG* at 1.

Meanwhile, the continued deregulation of electricity markets in the U.S. and Europe, the energy shortages that resulted from the wholesale competition in California in the late 1990's, the rise of the digital economy (and the associated need for reliable power) and increasing local opposition to the construction of new transmission lines have contributed to a rise in developed countries of the use of distributed generation – electricity generation close to the point of use. Unlike conventional central power plants that produce 100 to 1000 Megawatts (MW) or more of electricity, distributed generation facilities are smaller, ranging in size from 10 watts (W) to 50 MW. Distributed generation, often referred to as DG, includes everything from conventional diesel generators and industrial cogeneration units to small solar photovoltaic (PV) systems. Distributed generation can be used for continuous power generation (either stand-alone or with grid backup); to power local mini-grids; to provide standby power to run during power outages or peak periods when electricity prices are highest; provide supplemental power to households; or to export power back to the electricity grid, helping reduce congested and overburdened distribution systems. The increased emphasis on distributed generation has also resulted from widespread advances in DG technologies and concerns over the environmental and climate change impacts of traditional electrical generation and distribution systems.[11]

In the coming 30 years, demand for electricity in developing countries is expected to increase at an annual rate of 4.1 percent, nearly twice that of developed nations. Although rural populations without electricity are expected to gradually decline, rapid urban population growth will place an ever increasing strain on existing electrical generation, transmission and distribution systems.[12] To meet this growing demand, the IEA estimates that 2,382 GW of *new* electrical generation capacity will be needed at a cost of $2.13 trillion. The IEA concludes that developing countries will also have to invest in: (1) the extension of the electricity grid in urban areas; (2) mini-grids in medium-sized settlements; (3) decentralized installations providing thermal, mechanical and electric power in rural areas; and (4) maintenance and upgrading of existing infrastructure.

Table 1. Developing Country Electrification Rates (%) and New Electricity Generation Capacity and Investment by Region

	1990 Electrification Rate (%)	2000 Electrification Rate (%)	2000 Urban Electrification Rate (%)	2000 Rural Electrification Rate (%)	Additional Capacity (GW) 2000-2030	Cumulative Investment (billions $) 2000-2030
North Africa	61	90.3	99.3	79.9		
Sub-Sahara	16	22.6	51.3	7.5		
Africa	25	34.3	63.1	16.9	322	217
South Asia	32	40.8	68.2	30.1	345	315
Latin America	70	86.6	98.0	51.5	339	331
Brazil					123	158
East Asia/China	56	86.9	98.5	81.0	385*	338*
China					800	827
Indonesia					90	73
Middle East	64	91.1	98.5	76.6	191	101
Developing Countries	**46**	**64.2**	**85.6**	**51.1**	**2,382**	**2,130**
World	**60**	**72.8**	**91.2**	**56.9**	**4,821**	**4,168**

Source: IEA, WORLD ENERGY OUTLOOK 2002 at 377, 380 and 132.

* Without China.

[11] IEA, DG IN LIBERALIZED MARKETS at 20.

[12] IEA, ENERGY OUTLOOK 2002 at 373, 377 and 383.

With many developing countries struggling to make utilities economically sustainable and meet increased energy demand, the time is right for governments to re-evaluate their energy strategies and begin to take advantage of the possible benefits that DG can provide. New energy strategies at the local level are needed that reflect actual market and social conditions. Greater use of DG can help reduce peak loads and overall consumption, improve transmission and distribution reliability, reduce energy sector emissions, boost income for businesses that sell electricity to the grid, create jobs and broaden access to electricity in isolated areas where grid extension is uneconomical.

One of the challenges facing governments of developing countries, is how to increase access to DG technologies and promote greater energy efficiency and conservation while still ensuring that the existing electric utilities (many of which are financially unstable) remain viable and competitive. Under current electricity market reforms, even in developed countries, the benefits of DG are largely unrecognized. Among the barriers faced by DG include costly equipment requirements, high connection fees, lack of grid access and lengthy approval processes.[13] In developing countries the capital costs for new technologies is often very high, which often results in undeveloped natural gas and DG project infrastructure (an essential component for DG growth). Renewable energy DG technologies in developing countries either don't exist or are in their early stages of market entry and local knowledge of such technologies is usually rudimentary. Price distortions and fossil fuel subsidies also make renewable DG technologies less competitive.

Despite these challenges, developing country governments can begin to take a number of regulatory and financial measures to help level the playing field for DG and increase access to electricity in rural and urban areas. Governments can begin by standardizing technical and safety requirements for DG. A second step is to devise uniform interconnection standards to lower transaction costs for DG technologies and allow them to more fairly compete. Third, governments can ensure that DG receives non-discriminatory access to the distribution system and the ability to compete in the wholesale market for the provision of energy, reserve or ancillary services.[14] Fourth, governments should explore allowing customers with excess power from DG power systems to sell electricity back into the grid. The more access DG is provided, however, the more complex its management becomes. Regulators will need to address ways to adopt fair pricing systems that takes into account the grid-benefits of DG while fairly compensating utilities and distribution companies for other costs resulting from DG. Other barriers, such as cumbersome permitting and other regulatory requirements, including environmental impact issues, will also need to be addressed.

Overcoming regulatory barriers is only part of the equation for increasing the use and application of DG technologies. Governments must also take an active role to help create market opportunities for the widespread adoption of DG through tax incentives and credits, buy-down programs, low interest loans and guarantees, and public benefit funds for rural electrification. In doing so, governments must take care to ensure that subsidies are directed at lowing capital costs and not used to cover operating expenses. Finally, developing countries should support the development of human capital and entrepreneurs. DG is not a cure all for developing country energy needs and problems. Nevertheless, with the right regulatory policies, incentives and government commitment, DG can help expand access to energy and provide numerous other ancillary benefits to developing countries.

[13] NREL, *Making Connections* at 34.

[14] IEA, DG IN LIBERALIZED MARKETS at 105-107.

2. Distributed Generation Applications and Technologies

2.1 What is Distributed Generation?

Distributed generation is the generation of electricity near the place of use or close to the load being served.[15] Beyond this broad definition, there is no consensus on what constitutes distributed generation. Some regulatory bodies limit the definition to electricity generation near the place of use that is connected to the transmission or distribution system.[16] The IEA defines distributed generation as "a generating plant serving a customer on-site or providing support to a distribution network, connected to the grid at distribution-level voltages."[17] Others limit the definition by size or type of generation.[18] For purposes of this publication, distributed generation includes *electricity generation or storage close to the point of use, including on-site generation that is connected to the distribution grid or a mini or micro-grid*.[19]

2.2 DG Applications

Distributed generation includes both fossil fuel and renewable energy technologies and can be used for a variety of different purposes. For example, distributed generation can be a simple independent power source used for back-up power or a complex system that is connected to the electricity grid and involves electricity generation, energy storage and power management systems.[20] The following are some of the different DG applications:

1. **Self-Sufficiency and Grid Independence.** DG technologies can be used for continuous on-site customer electrical power generation to meet all of one's energy needs with or without grid connection. Grid connection is often desirable for backup power should the DG technology fail or during maintenance outages. This also includes mini-grid applications. Improved power quality and reliability are two of the primary drivers for on-site distributed generation. Off-grid, stand-alone power generation is also used for village and rural power applications in areas that are difficult to access and not served by the

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[15] CAL. ENERGY COMM., DG STRATEGIC PLAN at 2. *See also,* Resource Dynamics Corp., at 28.
[16] The California Energy Commission defines distributed generation as: "electric generation connected to the distribution level of the transmission and distribution grid usually located at or near the intended place of use." CAL. ENERGY COMM., DG STRATEGIC PLAN at 2.
[17] IEA, DG IN LIBERALIZED MARKETS at 10.
[18] The Public Utility Commission of Texas's Distributed Generation Interconnection Manuel defines distributed generation and on-site distributed generation as: "An electrical generating facility located at a customer's point of delivery (point of common coupling) of 10 MW or less and connected at a voltage less than 60 kV, which may be connected in parallel operation to the utility system." PUBLIC UTILITY COMM. OF TEXAS at A1-3.
[19] This definition is similar to what the IEA defines as "dispersed generation," "distributed generation plus wind power and other generation, either connected to a distribution network or completely independent of the grid." IEA defines "Distributed Power" as "distributed generation plus energy storage technologies such as flywheels, large regenerative fuel cells, or compressed air storage;" "Distributed Energy Resources" as "distributed generation plus demand-side measures;" and "Decentralized power" as "a system of distributed-energy resources connected to a distribution network." IEA, DG IN LIBERALIZED MARKETS at 19 and 20. The California Energy Commission defines a micro-grid as: "A micro-grid is a grouping of small-scale generators that are owned and operated by energy users who are members of the micro-grid. The micro-grid is operated entirely in the customers' own interests and has only one point of interconnection with the utility grid." CAL. ENERGY COMM., DG STRATEGIC PLAN at 15.
[20] Govt. of India, *Report of the Committee on DG* at 3.

electricity grid.

2. **Supplemental Power.** On-site generation can be applied to augment power from the grid. This can be out of the desire to provide standby or emergency power during grid outages. DG can also be used to reduce the amount of electricity purchased during peak pricing periods (peak shaving).
3. **Net Energy Sales or Metering.** Customers who install distributed generation (homeowners, businesses or entrepreneurs) that produce excess on-site power can sell their surplus electricity back to the electricity grid, particularly during peak pricing periods. This is often called "net metering."
4. **Combined Heat and Power or Cogeneration.** Industrial processes or power generation can use captured waste heat to enhance energy efficiency and help meet a customer's hot water, space heating or other thermal or cooling needs.
5. **Overall Load Reduction.** Supplemental DG power and other energy efficiency and saving measures can also be used to reduce electricity consumption from the grid (demand-side-management).
6. **Grid Support.** DG can also be used by power companies to reduce congestion during high peak loads as a way to avoid having to invest in expensive line and sub-station upgrades.[21]

2.3 DG Fossil Fuel Technologies

Fossil fuel technologies remain the primary source of distributed generation in both developed and developing countries. The three primarily fossil fuel uses are: reciprocating engines, combustion gas turbines, and micro turbines, with the later still in the development stage. Most fossil fuel technologies run on natural gas or diesel. However, natural gas infrastructure is not always prevalent in many developing countries and the gas often has to be imported. Many fossil fuel technologies can have high emissions. Given the need for many countries to import fossil fuels, some developing countries are beginning to experiment with indigenous fuels that use modified combustion engines.

Reciprocating Engines

Reciprocating or internal combustion engines are the most widely used for DG applications, mainly for standby or emergency power for small industrial or commercial customers. This is due to their fast start-up time and wide availability.[22] However, with high efficiency levels and low fuel costs, reciprocating engines can also be utilized for continuous power applications. Reciprocating engines include compression-ignited diesel and four cycle spark-ignited Otto engines.[23]

Typical efficiencies range from 25 to 36 percent, although large modern diesel engines that are capable of running on heavy fuel oil or crude oil can attain electric efficiencies close to 50 percent.[24] Newer reciprocating diesel engines are capable of substituting diesel with 89 to 90 percent gasoline or natural gas that emits fewer emissions. By recovering the heat from the

[21] *See*, Govt. of India, *Report of the Committee on DG* at 3-4 and Distributed Generation Applications at http://www/distributed-generation.com.
[22] USDOE, *Review of CHP Technologies* at 11.
[23] Resource Dynamics Corp. at 9.
[24] Id. at 7 and Petrie, E. at 5.

engine's exhaust, approximately 70 to 80 percent of the fuel's energy can be utilized.[25] Average cost is between $200 to $350/kW for normal reciprocating engines[26] and $800 to $1,500/kW for combined heat and power projects.[27] Maintenance costs are $0.01 to 0.015/kWhr. Although reciprocating engines are widely available, inexpensive, and efficient, they have high maintenance requirements, and diesel units have a higher level of emissions.[28]

Combustion Gas Turbines

In OECD countries,[29] gas turbines make up two-thirds of the 2000 orders of 20 GW distributed generation systems. Half of the orders are for standby units, 40 percent for continuous use and 15 percent for peak capacity.[30] Gas turbines range from 1 to 10 MW for onsite power generation, and they can operate using natural gas, synthetic gas and fuel oils.[31] Simple cycle efficiencies are between 25 to 40 percent with newer combined cycle turbines. These combine a gas turbine with a heat recovery steam generator – typically above 25 MW – achieving electric efficiencies around 60 percent. Capital costs range between $300 to $900/kW with average maintenance between $0.003 to $0.005/kWhr.[32]

Micro Turbines

Micro turbines are 25 kW to 250 kW turbine engines that run on natural gas, gasoline, diesel or alcohol.[33] Derived from aircraft auxiliary power systems and automotive designs, micro turbines have one or two shafts that operate at speeds of up to 120,000 revolutions per minute for single shaft engines and 40,000 rpm for duel shaft engines. Micro turbines are a relatively new technology and are only now being sold commercially. They have capital costs of $500 to $1,000/kW and electrical efficiencies of 20 to 30 percent.[34] Their main advantage is their small size and relatively low NO_x and CO_2 emissions. Main markets include light industrial and commercial facilities that often pay higher prices for electricity.[35] Their modest heat output can also be used for low pressure steam or hot water requirements.[36]

2.4 Combined Heat & Power

Combined heat and power (CHP, or cogeneration) can produce substantial cost savings for industrial and commercial users, providing an important source of additional electrical power, hot

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[25] *Id*.
[26] Petrie, E. at 5.
[27] USDOE, *Review of CHP Technologies* at 8.
[28] Resource Dynamics Corp. at 9.
[29] The Organization for Economic Co-operation and Development (OECD) includes Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the U.S. IEA, ENERGY OUTLOOK 2002 at 2.
[30] *Id*. at 15 and 31.
[31] USDOE, *Review of CHP Technologies* at 17.
[32] *Id.* at 15-18.
[33] *Id.* at 20.
[34] Petrie, E. at 3.
[35] USDOE, *Review of CHP Technologies* at 22. An assessment of distributed generation technologies prepared for the Maine Public Utilities Commission rated micro turbines as having a "moderate fit" for such distributed generation applications as continuous generation, combined heat and power and peaking. *See,* Resource Dynamics Corp. at 13.
[36] USDOE, *Review of CHP Technologies* at 22.

water, low and high pressure steam consumption and cooling loads, while reducing energy consumption and lowering emissions.[37] Apart from electricity generation, steam turbines can also be used to operate rotating equipment such as air or refrigeration compressors. In the state of São Paulo, the natural gas utility is providing incentives for natural-gas powered CHP as a way to increase market share.[38]

Industrial applications provide the greatest potential for CHP in agriculture, forest products, lumber and wood products, paper and allied products, mining, glass, petroleum, chemicals and metals and food processing.[39] In a study of the U.S. market, the following sectors were identified as having potential: colleges, universities and schools, district energy utilities, government, hospitals, solid waste (using landfill gas and biogas from sewage treatment facilities), office buildings, apartments, airports, prisons, supermarkets, nursing homes and warehouses.[40] One advantage of combined heat and power is that it can be used with a wide array of technologies, including fuel cells. Gas turbines or reciprocating engines are the two primary technologies used for industrial, commercial or institutional end users.[41] Another source is biomass fuels, such as bagasse from sugar cane.

Box 1. *Case Study: Sugar Mill Cogeneration in India*[42]

With policy support and promotional assistance from the Indian Ministry of Non-conventional Energy Source, the Indian Government, and USAID, state power boards began offering sugar mills 13-year power purchase contracts at a competitive price of $0.06/kWh, and a 50 percent reduction in interconnection fees. As a result, India's sugar mills now produce and sell over 300 MW of electricity to state grids using a high pressure and temperature cogeneration process with bagasse, a renewable fuel and byproduct from sugar cane. An additional 400 MW surplus of exportable bagasse energy is in advanced stages of development and over 3,000 MW is planned for year-round cogeneration. The total development potential for bagasse in India is believed to be 5,000 MW. The benefits provided by India's bagasse cogeneration program extend far beyond the additional electricity generated. From 1999 to 2000, four sugar mills alone offset 359,000 tons of carbon dioxide emissions. The growth of electricity generation as a byproduct of sugar mills also creates jobs, fortifies rural and local economies, and helps avoid further migration to overcrowded cities.

Economy of scale is important in CHP applications due to the amount of capital investment required. The higher the utilization rate the more economical CHP becomes. In OECD countries,[43] the capital costs to combine both power and heat production increase on average by 10 percent. This may well be higher in developing countries due to the increased cost of capital. Nevertheless, studies show that the additional costs are almost always recovered by the value of excess heat energy produced, sometimes in as little as two to five years.[44]

One downside to CHP is that is it is very site specific due to the need for customers to use the process heat.[45] Because developing countries tend not to be highly industrialized, they also do not have a large demand for the process heat, and where there is demand, it normally is in select

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37 *Id.* at 28-29.
38 Interview with Michael D. Philips, Energy Ventures International, December 2003.
39 Oak Ridge Nat. Lab., at 40.
40 USDOE, The Market and Technical Potential for CHP at 5 and 14.
41 USDOE, *Review of CHP Technologies* at 28-29.
42 Winrock International, brochure and presentation at the 3RD INTERNATIONAL CHP AND DECENTRALIZED ENERGY SYMPOSIUM AND USAID INTERNATIONAL CONFERENCE AND EXHIBITION ON BAGASSE COGENERATION, at the Hotel Grand Inter-Continental, New Delhi, India (October 24-26, 2002).
43 *See* Note 29 for a list of OECD countries.
44 IEA, DG IN LIBERALIZED MARKETS at 40.
45 *Id.* at 40-41.

regions of the country. There is particularly little demand for process heat in rural areas.

2.5 DG Renewable Energy Technologies

Experiences with renewable energy technologies (solar, wind, biomass, geothermal, small hydro and fuel cells) in developing countries have been mixed. India and China have aggressively promoted its development, with relative success. Nevertheless, many barriers continue to impede its development. Foremost is the high up-front cost of renewables compared with fossil fuel technologies. DG renewable technologies continue to be inhibited by fossil fuel and electricity subsidies that do not reflect the true cost of generation and transmission. The intermittent nature of some renewables – their dependency on the availability of wind, water, sun, or biomass resources – may further limit their use. As a result, DG renewable technologies require the use of energy storage devices, (usually batteries, which are expensive and require maintenance) or back-up power, most often diesel generators. Renewable DG technologies normally require resource assessments before installation and the provision of support services and replacement parts is not always readily available.

There are, however, a number of benefits to renewables. Renewable DG technologies are not subject to fossil fuel price fluctuations.[46] Renewables in a DG context will often have an advantage when applied in mini-grid or off-grid rural settings where power line extensions are too costly or where line construction will take considerable time to complete. In China, for example, small hydro and solar power have been successfully applied to run DG mini-grids. High peak energy prices can also make DG renewable energy economically attractive. Renewables also emit less pollution.

Solar Power

Solar energy is the direct conversion of sunlight into electricity using semiconductor materials called photovoltaic (PV) modules, of which there are roughly 30 different types. Three are under commercial production: monocrystalline modules are the most efficient; polycrystalline modules are less efficient but less expensive to produce; and thin-film modules, normally used for running consumer devices, are half as efficient as the best cells but far less expensive.[47] Thin film PV technologies offer the advantage of providing lightweight and unbreakable panels on flexible substrates that can be integrated with the roof. Solar PV technologies can operate for up to 30 years, and are used worldwide. The global PV market is currently growing at a rate of approximately 20 to 25 percent per year.[48]

PV solar systems range in size from 50 watts to one kW for stand-alone systems (usually with battery storage) and 500W to five kW for grid-connected systems or larger remote water pump systems. A five-kW PV solar system can serve a village of 50 to 80 households. PV modules can also be integrated with diesel, wind and hydro systems and are cost-effective with other energy sources today in remote areas without access to electrical grids. PV panels are used for charging batteries in lanterns, village lighting, communications, refrigeration and water pumping. PV modules typically cost between $2.50 to $3.00/watt.[49] For example, solar home systems for lighting and basic household uses in developing countries can be as low as $350 to install. However, home systems have been slow to catch on, even for middle and upper income rural

46 The price of natural gas in Mexico in 2003 increased by nearly 40 percent.
47 UNEP, Solar Electricity Fact Sheet.
48 P.V. NEWS, March 2003.
49 U.S. Department of Energy, *Solar Energy Technology Roadmap*.

families, largely due to the lack of credit and poor installation and support systems.[50]

Wind Power

Wind turbines use the wind's kinetic energy to produce electricity, through a gear box and generator, or to operate mechanical devices, such as water pumps.[51] Small wind turbines range in size from 900W to 50 kW. Wind power is a proven technology and is used in more than 30 countries. It is estimated that small-wind power is available in 75 percent of the world. China alone has installed over 150,000 small wind turbines.[52] The availability of wind speed data is vital for determining the feasibility of wind projects. Although wind energy is intermittent, it is nevertheless a predictable resource that can be integrated into the electrical grid or used in mini-grid, often with other energy sources, such as solar or diesel generators.[53] In remote locations, variable speed wind turbines can be used to help stabilize distribution networks.[54] Small wind turbines with only two to thee moving parts are mechanically simple, rugged, reliable, and last up to 50 years. They require virtually no maintenance and can be used off-grid for pumping and treating drinking water, irrigation, telecommunications, homes, schools, clinics or for supplementing larger village power systems. A village wind power system that provides up to 500 kWh per month ranges in cost from $15,000 to $25,000, with larger systems prices as high as $150,000.[55] A 7.5 kW wind turbine and battery charging station that supplies electrical power to 40 homes in Tomenas, in Timor costs each family approximately $2.40 per month.[56]

Biomass and Biofuels

Biomass energy comes from wood chips, aquatic plants, corn cobs and stalks, rice hulls, nut shells, orchard prunings, alcohol, sugarcane bagasse and vegetable oils, and municipal and animal waste (biogass). Biomass energy is produced either through *direct combustion* (usually solids in furnaces or boilers), through *anaerobic digestion* (accelerating the natural conversion of biomass into methane-rich biogas for use as a gaseous fuel), *gasification* (the physical or chemical conversion of biofuels into secondary gaseous compounds used as a fuel), or *chemical or biochemical conversion* (using yeast to decompose carbohydrates such as starches in grains, sugar cane juice or molasses to produce methanol, ethanol or other liquid fuels).[57]

Biomass power plants range in size from four kW to as large as 50 MW and have tremendous potential in developing countries. In India alone, Winrock International estimates that 19,500 MW can be generated from fuel wood and crop residues and bagasse from the sugar industry.[58] According to the World Alliance for Decentralized Energy (WADE), with the right tariff structure bagasse has the potential to provide sugar mills around the world with heat and power and still be able to export anywhere from 60 to 80 percent of the power generated.[59] The conversion of sugar

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[50] *Id. See also,* Císcar, J.C. Database of State Incentive for Renewable Energy (DSIRE) http://www.dsireusa.org; February 2004

[51] UNEP, *Wind Power Fact Sheet*.

[52] Bergey, S*mall Wind Systems for Rural Energy*. *See also,* Bergey, *Small Wind Systems for Village Power: An Update*.

[53] UNEP, *Wind Power Fact Sheet*. Utilities can normally accommodate 20 to 40 percent of its generation capacity from intermittent wind sources. *Id*.

[54] *Id*.

[55] *See*: http://www.bergey.com and http://www.wind-power.com.

[56] Bergey, *Small Wind Systems for Rural Energy*.

[57] See, ARMSTRONG, A. J., RE POLICY MANUAL at Appendix A and UNEP, Bioenergy Fact Sheet.

[58] *See*, http://www.renewingindia.org/biogs.html.

[59] WADE, *Future of Environmentally Responsible Energy Systems*.

cane to alcohol in Brazil is beginning to compete with gasoline, although the country's alcohol fuel program has relied on substantial subsidies over the years. Biogass plants also require sufficient space and a constant fuel source.[60]

Biomass is also an excellent source of power for remote village applications. A number of commercial companies, including Ormat International and Community Power Corporation, manufacture small stand-alone biomass units from 4 to 15 kW for village power applications. Ormat's new Biomass Fuel Power Unit "E4V," for example, is a self-contained, fully automatic power system that can be skid-mounted and operated by local farmers using various types of biomass and agricultural residue.[61] The Community Power Corporation has also developed a bio-power battery charger that uses a gasifier to operate a free-piston Stirling engine generator. The company is also working to develop systems that produce clean gas from biomass to power fuel cells and micro-turbines.[62] As the following case study below demonstrates, innovative uses of biomass crops, such as switch grass and plant extracts are increasingly being used as a replacement for diesel fuel.

Box 2. *Case Study: Village Power Using Biofuel in India as a Replacement for Diesel*[63]

In the remote village of Chalpadi in the Indian State of Andhra Pradesh, oil extracted from the seeds of the local pongamia pinnata tree is being used as biofuel to run an off-the-shelf diesel engine that provides power to a community-run village electrification micro-grid. The town originally received the diesel engine from the Indian government as part of its rural electrification program, but when the cost of diesel became prohibitive, the town turned to the idea extracting oil from pongamia seeds as a source of fuel to power the generator instead of diesel.

Villagers now "pay" for the operation of the generator and their electricity by collecting the seeds needed to make the biofuel. A women's self-help group responsible for the operation and maintenance of the engine levies a weekly tariff of 7 kilograms of pangamia seed per family. In April 2003, the town of Chalpadi sold 900 tons of carbon-dioxide equivalent verified emission reductions to Germany. The sale, which was facilitated by former World Bank economist Dr. Emmanuel D'Silva, fetched the community $4,164.00, equal to a year's worth of income for every family in the village.

The state government has plans to replicate the project in some 100 villages. In addition, the federal government of India is actively encouraging biofuel production sources from pongamia and other oilseed-bearing tree species. The next phase of the Indian project is to form women's associations that will produce the seed, process the biofuel, and use the fuel to power irrigation pumps. The woman's associations will then sell water to local farmers as a woman-owned business enterprise.

Geothermal

Geothermal power uses the natural heat from the earth's interior to drive a turbine generator and produce electricity. Direct geothermal energy is used in 60 countries for commercial purposes, such as agricultural (mainly greenhouse heating), aquaculture (fish pond heating) and industrial processes.[64] Although geothermal energy is generally not considered a distributed resource, as it normally provides large base loads of up to 100 MW connected to the electricity grid, small geothermal energy systems can be used for mini-grid applications. Smaller geothermal energy plants of less than 5 MW are in use in China, Mexico and Thailand and have potential in Central and Latin America, the Caribbean, East Africa and the Philippines.

[60] Govt. of India, *Report of the Committee on DG*, at 32.
[61] These include rice husks, maize cobs, coffee husks and pulp, sugarcane tops, wood chips and sawdust.
[62] For more information visit: http://ormat.com and http://www.gocpc.com.
[63] Erik Streed, USAID, EGAT. For further details on the program, contact ehdesilva@hotmail.com.
[64] UNEP, *Geothermal Fact Sheet*.

Small-sized units are readily available in 250 and 500 kW steam units.[65] A 300 kW geothermal power plant built by Ormat in Fang, Thailand not only generates electricity but also uses the spent hot water to operate a cold storage house and a crop dryer. Costs for geothermal energy plants in the 1 to 5 MW range are between $0.05 to $0.07/kWh, while smaller geothermal electrical systems are higher, between $0.105 to $0.30/kWh. The cost of geothermal energy competes with that of diesel in the 100 to 1000 kW size range.[66] Unlike intermittent technologies, geothermal energy provides constant power at 80 percent capacity or higher.

Small Hydro

Hydropower converts falling water into electrical energy or mechanical energy. The amount of power provided by the falling water is a function of the vertical distance the water drops (the head) and the volume of the water passing through the turbine. For example, 50 cubic meters of water falling 10 meters (a low head application) represents the same energy potential as 10 cubic meters of water falling 50 meters (a high head application).[67] Brazil defines small hydro as 1,000 to 30,000 kW installed capacity, mini-hydro as 100 to 1,000 kW and micro-hydro as up to 100 kW.[68] Small hydro systems require a turbine, generator, water-flow controllers and a structure to house the equipment.[69]

Depending on its size, the construction of a small hydroelectric project can take between two to three years at a cost of $1,000 to $5,000/kW, 45 percent of which is for equipment, 27 percent for labor, 15 percent for development and 13 percent for infrastructure. Sites with a fast water flow (high head) will usually require smaller and less expensive turbines and equipment. While most hydroelectric projects use a storage reservoir to supply water to the turbine, "run-of-river" systems capture the energy in the water by placing a special turbine in the river. Such systems are susceptible to low water flow, however. Well-planned small hydro systems have minimal environmental consequences and a project life of 20 to 30 years.[70] The life-cycle cost of a small hydro project is between $0.05 to $0.15 kWh. There are extensive opportunities for small hydro in Southeast Asia and Latin America.

Fuel Cells

Power from fuel cells is created through an electrochemical process with (no moving parts) that uses hydrogen (usually derived from natural gas) and oxygen to produce a DC current, heat, water and carbon dioxide. There are presently four types of fuel cells being developed for electrical power generation: (1) phosphoric acid fuel cells; (2) molten carbonate fuel cells; (3) solid oxide fuel cells; and (4) proton exchange membrane fuel cells. Phosphoric acid fuel cells have a 40 percent energy efficiency and are presently on the market mostly in the 200 kW range. Molten carbonate fuel cells and solid oxide fuel cells produce high temperatures and have 60 percent efficiency. Proton exchange membrane fuel cells operate at lower temperatures and are used for small-scale operations.[71]

Fuel cell efficiency can reach as high as 85 percent with combined heat and power applications. Fuel cell and gas turbine hybrid systems are also being developed (see hybrid discussion below).

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65 Vimmerstedt, L. at 21.
66 *Id.* at 114-115 and 117.
67 UNEP, *Small Hydro Fact Sheet*.
68 Winrock, *Trade Guide on Renewable Energy in Brazil* at 32.
69 UNEP, *Small Hydro Fact Sheet*.
70 *Id*.
71 USDOE, STRATEGIC PLAN FOR DISTRIBUTED ENERGY at 15. *See also,* Resource Dynamics Corp. at 18.

The main barrier to fuel cells is their cost which range from $1,000 to $1,150 per kW with operating costs estimated at $0.08 to $0.10/kWh. Fuel cells emit very low levels of nitrogen oxides (NO_x), sulfur oxides (SO_x), carbon monoxide (CO), and carbon dioxide (CO_2) when hydrogen is extracted from natural gas or other hydrocarbon fuels.

2.6 Hybrid Energy Systems

Hybrid power systems are those that use more than one generation technology. CHP systems, discussed above, are but one example of hybrid systems. Hybrids can include any combination of renewable and fossil fuel generation technologies or different renewable sources, such as wind, solar and small-hydro, which are normally combined with battery storage. Hybrid systems are capable of providing reliable "grid quality" AC power sufficient to support standard appliances, such as refrigerators.

One hybrid system under development is the use of fuel cells and gas turbines. These highly efficient systems eventually will be able to produce 30 MW or more of electrical power at a 70 percent efficiency.[72] Because wind and PV solar power systems are intermittent, hybrid systems can allow one technology to distribute power when the other is idle. For example, wind or mini-hydro and solar PV modules often have seasonal compatibility. During summer months there is generally less wind and water but lots of sun, while in the winter there tends to be more wind and water and less sun.[73] For low load applications, a small 1.2 kW wind/solar hybrid system capable of producing between 3 to 5 kWh per day can be installed by two people in less than a day at a total cost of approximately $5,900.[74] These systems are easy to ship and can operate in adverse terrain.

Villages throughout the world run diesel generators for three to six hours a day, providing electricity only during evening hours. Wind/diesel or Wind/solar/diesel hybrid systems, however, can provide electricity 24 hours per day and are ideal for village mini-grid applications. Existing diesel mini-grid systems, for example, can be retrofitted with larger size AC type induction generator wind turbines. Typically, renewable energy in a hybrid system will supply between 60 and 80 percent of the energy with diesel generators running as little as 10 percent of the time. One downside to such systems is the necessary watering of the battery banks, which represents an operational burden.[75]

3. The Advantages and Disadvantages of Distributed Generation for Developing Countries

Distributed generation offers a number of different benefits for power consumers, generators, distribution companies, independent power producers and society as a whole. For one, it offers consumers more efficient, reliable and flexible power at a reasonable cost. In addition, it can provide utilities and distribution companies with a number of ancillary services, such as reduced congestion and lower transmission and distribution losses.[76] However, there are also technical and safety issues associated with DG technologies that negatively impact utilities.[77]

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[72] USDOE, STRATEGIC PLAN FOR DISTRIBUTED ENERGY at 16.
[73] Bergey, *Small Wind Systems for Rural Energy*.
[74] *Id*. *See also,* Bergey, M. and Trudy Forsyth.
[75] *Id*.
[76] IEA, DG IN LIBERALIZED MARKETS at 40 and Onsite Sycom Energy Corp. at 12. IEA defines ancillary services as reserve and reactive power and the control of the frequency and voltage of electricity. IEA, DG IN LIBERALIZED MARKETS at Note 17.
[77] Arthur D. Little, Inc. at 7.

3.1 Off-Grid Remote Applications

One area where renewable DG technologies can excel is in rural applications where consumption is low and the distance to the nearest distribution center is high. Most off-grid opportunities for distributed generation are in Africa, Asia and select areas in Latin America, with Asia accounting for largest off-grid population. Deciding between grid connection and the use of DG technologies depends on a variety of technical, managerial and economic considerations that must be evaluated on a case by case basis.[78] Recent studies conducted by the World Bank suggest that a majority of off-grid populations can be served most economically through grid extension.[79] Nevertheless, much depends on the load requirements of a given area and the cost of expanding transmission and distribution lines. As Table 2 below indicates, these costs can vary considerably, ranging anywhere from $40 to $2,000 per kW of new peak load with a wide gap between rural and urban systems.[80] For example, solar power in Kenya has been found to be more economical than grid-supplied electricity when located 9 kilometers or more from the electricity grid.[81] Similar figures exist for Nepal. Other studies have shown solar and the adoption of energy efficiency measures to be cost-effective when compared with extending residential lines as little as ¼ mile.[82]

Table 2. Incremental Transmission & Distribution Expansion Cost in $/kW of New Peak Load for Several Electric Utility Systems[83]

Utility	Low $ / kW	High $ / kW
Europe – North Central Urban System	290	846
Unites States – Northeast	166	925
Unites States – Southeast	45	729
Unites States – Central Plains	82	336
Unites States – West Coast	64	610
Central America – Urban System	51	300
Central America – Rural System	51	920
Caribbean	65	518
Southeast Asia – Urban System	29	400
Southeast Asia – Rural System	40	2000

Because consumption levels in rural areas are often low with the primary use being for lighting, DG technologies are often initially the most appropriate option. DG home systems or mini-grids in rural areas can be very attractive, particularly when there is a low electricity load requirement. A recent comparison between the cost of providing low load electrical services through an 80 kilometer extension of the grid to a rural population center versus using distributed solar home systems, found that the break-even point was slightly above 7,000 customers.[84]

Even when grid extension is determined to be the most cost effective or appropriate given a population's electrical power needs, DG technologies may still be an interim solution that can be rapidly applied. This is particularly true for critical services such as water pumping and purification, healthcare, lighting, telephone, computer and internet services. Once the grid is

[78] Govt. of India, *Report of the Committee on DG* at 47-48. These include the distance from the grid, the amount of system losses, the load density and management issues.
[79] Interview with Michael D. Philips, Energy Ventures International, December 2003.
[80] Petrie, E., Table 2 *citing* WILLIS, H. L., DISTRIBUTED POWER GENERATION.
[81] Winrock, *Electricity on Demand* at 22.
[82] Moskovits, D. at 17.
[83] Petrie, E., Table 2 *citing* WILLIS, H. L., DISTRIBUTED POWER GENERATION.
[84] Ellegård, A., *Solar Service is Rural Infrastructure* at 7-8.

extended, distributed generation technologies can be moved and re-used elsewhere.

The use of distributed generation in remote areas also has the added advantage of enhancing the quality of rural life.[85] According to the World Bank, the benefits of decentralized energy are often under-counted.[86] The World Bank notes that "the economic benefits of electricity may be difficult to measure on the basis of the cost of substitutes. For instance, because electric lighting provides an order of magnitude improvement over lighting from candles and kerosene, electric light is much more than a simple replacement for kerosene."[87] Distributed generation can reduce the time women and children spend collecting water and improve health through water treatment devices and the electrification of clinics.[88] Access to electricity helps improve security, allow participation in community and school activities and extend work hours. It also helps improve a community's access to information and promotes a sense of being part of the modern world.[89]

Studies show that rural electrification by itself does not necessarily trigger economic development unless other prerequisites of sustainable development exist, such as markets for farm produce, transport infrastructure, education, skilled labor and communication services.[90] The one exception, however, is the use of electricity for pumping water for irrigation that often leads to agricultural growth and improved food security.[91] Distributed generation is particularly suited for water pumping applications. Other examples of productive DG applications include the use solar-powered lighting in India for pest control and micro-hydro in Nepal for grinding grain.[92]

3.2 Consumer Benefits

Increased Power Quality, Greater Flexibility and Lower Costs

Voltage fluctuations in the electricity grid and blackouts are responsible for large economic losses and increased production costs for goods and services.[93] Even in advanced grids, such as in the United States, there are widespread surges, swells and transients that hurt sophisticated controls, sensing, communications and computing equipment. In developing countries, these power swings are even more extreme, negatively impacting industry, healthcare providers and businesses that rely on computers and require high quality power.

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85 *Winrock, Electricity on Demand* at 18. *See also*, World Bank Operations Department, *Rural Electrification*.
86 Cecelski, E., *Enabling Equitable Access to Rural Electrification*.
87 World Bank Operations Department, *Rural Electrification*.
88 Cecelski, E., *Enabling Equitable Access to Rural Electrification* at 30.
89 *See*, UTONIH, S. P., POWER SECTOR REFORMS at iii.
90 *See,* World Bank Operations Department*, Rural Electrification;* Cecelski, E., *Enabling Equitable Access to Rural Electrification* at 22; and Ellegård, A., *Solar Service is Rural Infrastructure* at 8. The World Bank notes that "[r]ural electrification should ideally be introduced in areas where there is already a demand for electricity-using services — usually where there is agricultural growth, rural businesses and rural incomes." Sanghvi, A., *Rural Electrification: Lessons Learned*.
91 Winrock, *Trade Guide on Renewable Energy in Brazil* at 6. See also, World Bank Operations Department, *Rural Electrification*.
92 *Id.* Higher loads are required for machine and craft shop electrical uses which are usually obtained either from diesel or a wind/solar/diesel hybrid mini grid system. Wind and small hydro may also be capable of providing such loads under proper conditions.
93 WADE, *The Real Benefits of Decentralized Energy* at 2. *See also,* Lamech, R.. Most power outages are the due to failures in the distribution system. The U.S. Department of Energy estimates that the cost to business of one hour without power can range from $41,000 for a cellular communications firm to $6.5 million for a brokerage firm. IEA, DG IN LIBERALIZED MARKETS at 48-49 and Table 5.

In response to the poor power quality and high costs, households, apartment complexes and companies in developing countries are increasingly resorting to distributed generation to provide uninterrupted or standby emergency power to protect them against the risk of power outages and avoid high electricity prices.[94] In many instances, distributed generation can help bring down the cost of electricity when one takes into account true delivery costs and line losses.[95] Self-generation in developing countries accounts for 13 percent of all power generated. The percentage of self generation in Africa is even higher, equaling 25 percent of all electrical power.[96]

Flexibility is another important attribute of distributed generation.[97] When DG is readily available it can respond rapidly to inadequate distribution of electrical power and fuel price fluctuations. Newer generators can also operate using multiple types of fuel, including fuels generated from bio-gasification[98] (see section on Biomass energy below). DG can also be deployed by a wide range of market participants from end-use customers and businesses to utilities and energy service companies.[99]

Reduced Demand and Peak Shaving Benefits

Distributed generation can be operated to reduce energy consumption, shave peak power demand, or both.[100] In liberalized electricity markets, large customers often pay time-of-use rates where the energy charge varies according to season (e.g., summer has higher electricity demands than winter), time of day (mid morning to late afternoon is more expensive) and to the day of the week (workdays are more expensive than weekends or holidays).[101] Particularly during peak periods, distributed generation can be used to hedge against volatile prices. In many instances, DG technologies may be cheaper than peak time-of-use rates.[102]

3.3 Grid-Side Benefits and Costs

Siting, Planning and Construction Benefits

Distribution systems in many developing countries are already capacity-constrained. With 95 percent of population growth over the next 30 years destined to take place in urban areas, there is an urgent need to boost power and upgrade and expand distribution lines. System upgrades in urban areas, however, require much greater investment per kilowatt than more standard generation

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[94] To ensure a smooth transition from grid power to on-site power generation, electric storage and switching equipment is used. CAL. ENERGY COMM., DG STRATEGIC PLAN at 2. For example, industries with continuing manufacturing processes (chemicals, paper and others) or that provide essential services (banks, telecommunications, data storage and retrieval, hospitals, grocery stores) increasingly depend on reliable uninterrupted power supply. IEA, DG IN LIBERALIZED MARKETS at 48-49.

[95] WADE, *Future of Environmentally Responsible Energy Systems*.

[96] Kozloff, *Electricity Sector Reform in Developing Countries*.

[97] IEA, DG IN LIBERALIZED MARKETS at 38.

[98] Petrie, E., at 2.

[99] Arthur D. Little, Inc. at 2. The flexibility of DG also means that it is compatible with market-driven industry restructuring policy objectives.

[100] CAL. ENERGY COMM., CAL. INTERCONNECTION GUIDEBOOK at 34. For example, in Texas, renewable energy that is installed for self generation purposes, and "reduce[s] a customer's net purchase of energy (kWh) and/or electrical demand (kW)" is classified as a renewable demand side management technology. *Id.* The use of solar thermal water heaters is but one example.

[101] Onsite Sycom Energy Corp. at 6.

[102] Onsite Sycom Energy Corp. at 6.

and transmission improvements. [103] Engineering solutions based on the central power plant model can also take years to design and install. Small DG systems can take between six and 18 months to plan and install compared with an average of three to five years for a large independent gas power plant.[104] Strategically placed, distributed generation can not only provide additional power but also prolong the life of overburdened distribution systems, thereby avoiding the need for costly upgrades. The modular nature of DG technologies and the relative speed with which they can be deployed means that they can be brought on line quickly and incrementally as the population grows.[105]

Increased Reliability

Greater use of distributed generation can also increase the reliability of the electricity grid. When numerous sources of distributed power generation are connected to the electricity grid the impacts of one or more of the DG systems failing has less of an overall impact on the entire system. Similarly, the ability for DG to sell power to other consumers in the same distribution network also increases its value and allows utility customers to contract for backup power.[106]

Transmission and Distribution Benefits

The IEA estimates that the loss of electricity from transmission and distribution lines world-wide in 1999 equaled 9.5 percent of the total global electricity supply.[107] Transmission losses in developing countries are much higher, ranging from 12 percent in the Philippines, to 20 percent in Cameroon and Zimbabwe, and to as high as 32 percent in Nigeria.[108] Transmission and distribution of electricity account for 30 percent of the cost of electricity in OECD countries and 40 percent of the costs for small household consumers.[109]

Because distributed generation is located close to the end-user (either connected to the electricity grid or as stand-alone power), it can avoid or reduce transmission and distribution costs and free-up space on congested distribution systems.[110] For example, when strategically placed along the distribution system near large loads, DG can reduce distribution line losses by lowering power demand. The reduction in transmission system congestion can at least temporarily reduce the need to upgrade transmission and distribution systems.[111] DG generation can also raise the voltage in the network, thus enhancing stability and improving the overall quality of the energy supply.[112]

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[103] Arthur D. Little, Inc. at 1.
[104] Petrie, E. at 1 and Figure 1.
[105] Petrie, E. at 2.
[106] *Id*. *See also*, *WADE, The Real Benefits of Decentralized Energy* at 2 and IEA, DG IN LIBERALIZED MARKETS at 39.
[107] WADE, *The Real Benefits of Decentralized Energy*.
[108] IEA, ENERGY OUTLOOK 2002 at 383.
[109] IEA, DG IN LIBERALIZED MARKETS at 33. *See also,* Moskovits, D. at 3. In the U.S., the average distribution rate is $0.025 per kilowatt-hour (kWh) but marginal distribution system costs can reach as high as $0.20 per kWh. A study of 124 utilities in the U.S. found that the average marginal transmission costs (transformers, substations, lines and feeders) were in excess of $700 per kW. *Id*.
[110] Petrie, E. at 1. See also, WADE, *Future of Environmentally Responsible Energy Systems*.
[111] IEA, DG IN LIBERALIZED MARKETS at 40 and 48. *See also,* CAL. ENERGY COMM., DG STRATEGIC PLAN at 6. The UK regulator, Ofgem, calculated that the embedded benefits of distributed generation (transmission network use of system charges avoided (demand and generation); balancing system use of system charges avoided; transmission losses charges avoided; balancing system administrative costs avoided; and avoided trading charges) were between $2.80 to $4.10 (USD). IEA, DG IN LIBERALIZED MARKETS at 79.
[112] IEA, DG IN LIBERALIZED MARKETS at 40 *See also,* CAL. ENERGY COMM., DG STRATEGIC PLAN at 6.

The export of electricity to the grid during peak periods is not only beneficial to the distributed generator but to energy service providers that are relieved from having to generate and distribute high cost power. In Mexico, high tariff rates have encouraged the supply of DG power to private consumers during peak hours. While the program has been successful in helping reduce congestion, one downside has been in the inability of the Mexican Federal Electricity Commission to control the amount of DG power provided into the system. Another issue is that almost all the power has come from diesel generators with no pollution controls.[113]

Utility Considerations

One drawback to the grid-side benefits of DG is that they are very location specific and difficult to measure and quantify. Utilities and distribution companies tend to view customer-side DG with skepticism, seeing it as a temporary solution. Utilities contend that for grid-side benefits to be meaningful they must be incorporated into long-term planning for transmission and distribution systems. Because utilities are responsible for system reliability they argue that they have control over DG equipment, either through contracting or direct dispatch control (the ability to switch systems on and off).[114]

In addition, not all of DG's end results are positive. In some instances utilities must install equipment to handle reverse power flows from DG electricity exported to the grid.[115] The export of power from remote distributed generation locations can also lead to losses in the distribution system.[116] Similarly, while the rise in voltage from adding electricity to the network can be beneficial, it can also require connections at higher voltages or transformer upgrades to improve voltage control. In Denmark, for example, a substantial increase in distributed generation reduced loading on 132kV and 150 kV transmission systems but required the expansion of high-voltage systems (400 kV).[117]

The connection of DG to the electricity grid also raises technical, safety, power quality and dispatch issues (see section 4 below). While the use of DG for self generation or to meet peak power demand will have little impact on the electricity grid, the more DG power that is dispatched into the distribution system the greater the operational complexity for utilities and distribution companies.[118] Another issue is the ability of the utility to rely on DG power when it is needed. Bagasse cogeneration, for example, is only available at certain times of the year (e.g., during sugar processing after harvest). Even with the addition of DG power, utilities may decide that they have to add new capacity to ensure a reliable power supply.

The interconnection of DG equipment to the grid also raises questions regarding the appropriate costs for providing electricity to augment DG loads or backup power during DG equipment failures, or for the export of DG power back into the electricity grid. An Arthur D. Little White Paper notes that "Transaction costs per unit of energy could also increase from DG market activity and settlements, since they are generally dependent on the number, rather than size, of

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Adding electricity to the network normally causes the voltage to rise which is a benefit when there are low voltage levels. IEA, DG IN LIBERALIZED MARKETS at 73-74, 94.

[113] Interview with Alejandro Peraza Garcia, Director General of Electricity, Mexico Energy Regulatory Commission, September 19, 2003. Mr. Peraza may be reached at: aperaza@cre.gob.mx.

[114] Arthur D. Little, Inc. at 7-8.

[115] *Id*.

[116] IEA, DG IN LIBERALIZED MARKETS at 40.

[117] *Id.* at 73-74, 94.

[118] Arthur D. Little, Inc. at 11.

transactions."[119] Another factor is the loss of revenue by the utility. Most utilities view DG as competition and are opposed to seeing their customer base eroded. Governments may also have concerns over lost utility revenues that must be recovered either through a tariff increase or a subsidy from the government (i.e., from taxpayers). The issue of revenue loss for developing country utilities is particularly important as many utilities are already financially unstable. Lost revenue may not be an issue if the utility can sell its power to other customers or if DG is installed to meet excess demands that the utility would otherwise not be able to meet. But even when a utility is able replace a customer, the new customers may not be equally credit worthy.[120]

3.4 Environmental Impacts, Access to Finance and Economic Considerations

Environmental Impacts

Distributed generation also raises important environmental issues. Fossil fuel DG technologies, for example, emit varying levels of emissions, including nitrogen oxides (NO_x), sulfer dioxide (SO_2), carbon monoxide, carbon dioxide, particulate matter (PM-10) and unburned hydrocarbons. DG can also have noise, visual and land use impacts, particularly when used in densely populated urban areas.[121] In India, for example, the most common use of DG has been on diesel generators, which are highly polluting.[122] Similarly, other fossil fuel DG technologies, including gas turbines, are unable to compete environmentally with the low emissions levels from large combined-cycle natural gas fired plants with state-of-the-art pollution control technology.

Proponents of DG note that distributed generation rarely displaces only one technology, such as natural gas.[123] They contend that since DG tends to displace a mix of new and existing power generation with higher average emissions, environmental benefits are usually obtained.[124] Gradually, developing country governments are becoming more sensitive to regional and global environmental concerns and are increasingly acknowledging the need to diversify their energy resources.[125] An important question for policy makers is how to reduce the use of more polluting DG technologies and promote cleaner renewable DG technologies that are almost always more expensive.

DG Finance and Access to Local Capital

Securing financing for energy projects in developing countries is no easy task and is one of the major barriers to its development. Following the demise of Enron, many international energy companies sold their foreign energy assets in developing countries and have limited their overseas investments. When private investment is made, it normally occurs in power generation and not transmission and distribution, and often requires a 20 percent or higher return on investment due in part to the high level of risk. Moreover, foreign direct investment is not equal for all nations. For example, Africa and South Asia only receive one quarter of all foreign investment in energy.[126]

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[119] Arthur D. Little, Inc. at 11-15.
[120] Industry and businesses that are best positioned to install DG technologies are often the most creditworthy.
[121] NARUC, *Review of Utility Interconnection Tariff and Contract Provisions* at 4-7.
[122] Govt. of India, *Report of the Committee on DG* at 6.
[123] Bluestein, J., *Environmental Benefits of Distributed Generation* at 10.
[124] *Id*.
[125] Armstrong, A. J., *Trends in Renewable Policies in Latin America* at 2-3.
[126] IEA, ENERGY OUTLOOK 2002 at 381.

One reason is that distributed generation projects generally have higher upfront capital costs ($/kW) and production costs ($/kWh) than larger central power plants, due to their smaller size. For DG renewable technologies, a higher ratio of capital costs to operating costs also requires long term financing at reasonable rates.[127] In most developing countries financiers are less familiar with DG renewable technologies, project developers often lack extensive project experience and renewable technologies and therefore lack a successful track record that Banks can point to. All of this results in higher completion and operating risks, which increase the cost of capital.[128]

While the financial challenges size will continue to be an impediment, because of their size DG projects in developing countries may be better positioned to access domestic capital markets, while larger central power projects will almost always need some international finance.[129] A case in point is Java and Bali in Indonesia, where disputes have flared between the government and independent power producers. As a result, international lenders and even multilateral agencies, such as the Asian Development Bank, have stopped investing in Indonesia's power sector. It is estimated that Indonesia needs $28.5 billion in investments by the year 2010 just to keep up with electricity demand.[130]

With, the state-owned power company, PLN, cash-strapped and unable to finance new projects, the government is turning to distributed generation from the private sector to help alleviate power shortages. There is 6,800 MW of captive power available from companies that were forced to build their own generation plants in the early 1990s to meet their need for consistent power. The government is also initiating an aggressive demand-side-management campaign to reduce consumption. Meanwhile, domestic banks are beginning to show increased interest in investing in the country's power sector due to the high demand.[131]

Economic Benefits

Greater use of distributed generation can have a positive impact on developing country economies and employment.[132] Central station power generation is one of the most capital intensive industries. Nevertheless, it is also one of the least labor intensive. The expansion and growth of DG technologies can help create manufacturing and energy service jobs.[133] Aggressive government support for renewable technologies in India in the late 1990s led to a rise in domestic wind-turbine manufacturing, mainly through joint ventures with foreign partners.[134] Expanded use of DG, such as cogeneration from bagasse in India and Brazil, has made their sugar industries more efficient and brought in extra revenue through the sale of excess electricity to the grid (see India bagasse case study above).

Since most distributed generation technologies rely in some form on fossil fuels, their overall impact on diversification fuel supply will be very limited.[135] Nevertheless, greater use of combined

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127 Younger, D. R., *The World Bank Group and Finance of Sustainable Energy Activities*. Combined heat and power, on the other hand, normally has a relatively short payback period of between two to five years, and the cost per kWh is often much less than central power. Onsite Sycom Energy Corp. at 12.
128 Younger, D. R., *The World Bank Group and Finance of Sustainable Energy Activities*.
129 Onsite Sycom Energy Corp. at 12.
130 Winrock, *Renewable Energy State of the Industry Report* # 9 at 24-26.
131 *Id.*
132 NARUC, *Review of Utility Interconnection Tariff and Contract Provisions* at 4-8.
133 *Id.*
134 Martinot, E., *Government Policies and Private Finance* at 51.
135 IEA, DG IN LIBERALIZED MARKETS at 93. IEA notes that even the hydrogen for fuel cells will likely come from natural gas. *Id.*

heat and power results in lower fossil fuel consumption, and renewable DG technologies, such as photovoltaic cells, wind, biomass, geothermal and small-hydro, can help reduce dependency on natural gas, even if in relatively small quantities.[136] Because renewable energy DG is locally available, it is not subject to price and supply fluctuations as is the case with fossil fuels.[137] Since most developing countries must import their fossil fuel, increased use of renewable technologies can help keep local currency in the country and lead to improved balance of payments.[138]

4. Distributed Generation Regulatory and Policy Considerations

4.1 Key Policy Issues Facing Distributed Generation

The barriers facing distributed generation, particularly for smaller projects, have been well documented in the U.S. and elsewhere. Financial barriers resulting from higher capital and up-front costs are but one. A study undertaken by the U.S. Department of Energy and National Renewable Energy Laboratory (NREL) distributed generation projects also found three other barriers to be prevalent: technical, business-practice and regulatory.[139] These barriers included costly equipment requirements, high connection fees and lengthy approval processes that often prevented smaller distributed generation projects from being developed. Box 3 below provides a ten-point plan prepared by NREL to reduce barriers to DG deployment.

Box 3. *NREL Ten-Point Plan to Reduce Barriers to Distributed Generation*[140]

Technical Barriers

1. Adopt uniform technical standards for interconnecting distributed power to the grid.
2. Adopt testing and certification procedures for interconnection equipment.
3. Accelerate development of distributed power control technologies and systems.

Business Practice Barriers

4. Adopt standard commercial practices for any required utility review of [DG grid] interconnection.
5. Establish standard business terms for interconnection agreements.
6. Develop tools for utilities to assess the value and impact of distributed power at any point on the grid.

Regulatory Barriers

7. Develop new regulatory principles compatible with distributed power choices in both competitive and utility markets.
8. Adopt regulatory tariffs and utility incentives to fit the new distributed power model.
9. Establish expedited dispute resolution processes for distributed generation project proposals.
10. Define the conditions necessary for a right to interconnect.

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[136] The IEA notes that the overall impact of distributed generation on supply diversification is limited since most DG technologies fun on some form on fossil fuel. Even the hydrogen for fuel cells will likely come from natural gas. IEA, DG IN LIBERALIZED MARKETS at 93.

[137] Winrork, *Electricity on Demand*, at 18. Even countries with petroleum resources can expand their hard currency revenues by conserving fossil fuels through increased use of renewable technologies.

[138] Bronicki, L. Y. *ORMAT's Experience in Implementing Geothermal Projects*.

[139] NREL, *Making Connections* at 34.

[140] NATIONAL RENEWABLE ENERGY LABORATORY, MAKING CONNECTIONS – CASE STUDIES OF INTERCONNECTION BARRIERS AND THEIR IMPACT ON DISTRIBUTED POWER PROJECTS at 37 (NREL/SR-200-28053, May 2000).

The challenge for policy makers is how to formulate a workable regulatory and policy framework that values the benefits of distributed generation and reduces industry, market and economic barriers to development while still protecting the grid's infrastructure and ensuring that new power sources do not threaten the financial viability of existing facilities.[141] Even though developing countries are at different stages of electricity reform, there are a number of measures that can be taken to promote greater use of distributed generation. See Appendix 2 for a useful list of policy and regulatory questions pertaining to the promotion and use of distributed generation.

4.2 Performance, Safety and Maintenance Interconnect Issues

Distributed generation involves both physical and market interface issues.[142] Physical interface issues include questions regarding safety, protocols, system impacts, reliability, standards and metering.[143] There are three ways in which distributed generation physically interfaces with the electric utility: (1) "parallel operation" – when a DG facility provides some or all of its required power while connected to the utility distribution system or exports excess generation back to the utility; (2) "momentary parallel operation" or "closed transition switching" – when a distributed generator operates in parallel with, and synchronized to, the utility long enough to ensure a smooth transition from the utility (normally one second or less); and (3) "isolated operation" – when the distributed generator does not operate in parallel with the utility.[144]

Any time an entity is connected to the electricity grid, system integrity, reliability and safety issues arise. To be connected to the grid, a control system on the distributed generator is required for the dispatch of electricity along with a communication system to initiate start-up in real-time. The control system can be operated by the customer, retail company, distribution company or an independent systems operator. Electricity markets and interconnect standards were not originally designed to accommodate the connection of small DG to the grid. Interconnect standards and procedures were originally developed within the context of a vertically integrated and regulated monopoly structure and applied only to large customized DG installations ranging from 5 to 50 MW.[145] To this day, utilities tend to deal with distributed generation on a case-by-case basis. The technical and regulatory requirements applied to DG are often complex, time consuming and costly. Nevertheless, utilities and distribution companies are often reluctant to simplify these processes due to safety and reliability concerns.

4.3 Interconnect Procedures and Agreements

In the U.S. a number of states have sought to overcome technical barriers to distributed generation by adopting pre-certification standards for certain DG equipment, thus ensuring adequate performance and safety.[146] The U.S. Department of Energy, working under the auspices of the

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[141] Arthur D. Little, Inc. at 2 and 26.
[142] Market interface refers to the competitive market relationship between distributed generation and other electricity suppliers. *See,* Arthur D. Little, Inc. at 11.
[143] *Id*. at 10.
[144] CAL. ENERGY COMM., CAL. INTERCONNECTION GUIDEBOOK at 29. In Texas a facility that parallels with the electric utility for 60 cycles or less is called "close transition switching" while California refers to it as "momentary parallel operation." *See*, The Public Utility Comm. of Texas, *Distributed Generation Interconnection Manual* at A2-10 *citing,* The Public Utility Commission of Texas Rules §25.212 (g), Technical Requirements for Interconnection and Parallel Operation of On-Site Distributed Generation.
[145] Arthur D. Little, Inc. at 13.
[146] The states of California, Texas and New York have developed standards and procedures to address technical and safety issues pertaining to distributed generation.

Institute of Electric and Electronic Engineers (IEEE), is developing a Draft Standard for Distributed Resources Interconnected with Electric Power Systems (IEEE P1547). Draft 11 of P1547 was passed by IEEE in June 2003. The final standard will address conditions necessary for the operation, testing, safety and maintenance of interconnected distributed resources. Standards make it easier for DG users and equipment manufactures to obtain swift review and compliance.

California, Michigan, Minnesota, New York and Texas have also developed their own DG interconnection standards. The Public Utility Commission of Texas and the California Energy Commission have both published DG interconnection manuals with technical and safety requirements, application forms, pre-certification requirements, and, in the case of California, a database of certified equipment.[147] Texas and California also use model interconnect agreements. Standard interconnect procedures and agreements have also been developed by the National Association of Regulatory Utility Commissioners[148] and the Federal Energy Regulatory Commission.[149]

The resolution of interconnect issues is critical because it establishes technical ground rules and credibility for distributed generation in the subsequent phases of policy development.[150] The first step in designing such a policy is to develop technical and safety requirements that address quality issues, "disconnect switches, minimum power factor requirements, and metering, monitoring and telemetry requirements."[151] A second step is to devise uniform interconnection standards and procedures to lower transaction costs. As in the case of Texas, rules and procedures should specify the pricing for transmission and distribution services and tariffs for back-up power, and set time limits for processing applications. Rules should also provide for dispute resolution procedures.[152] Finally, on-site equipment testing procedures to verify compliance with the technical requirements should also be established by the appropriate regulatory commission.

4.4 Market Access and Structure

With streamlined interconnection procedures, regulators can decide under what terms and conditions DG will be allowed access to the electricity grid, and how to meter and pay for such access. In a vertically integrated electricity market, distributed generation either displaces electricity from the grid or exports electricity back to the grid. Normally, this involves a long-term contract with the utility that includes special charges for backup power, ancillary services and the exported electricity.[153]

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[147] *See*, The Public Utility Comm. of Texas, *Distributed Generation Interconnection Manual*; California Energy Comm., *California Interconnection Guidebook*.

[148] *See*, NARUC, *Model Distributed Generation Interconnect Procedures* and Ohio State University, *Model DG Interconnection Procedures*.

[149] In July 2003, the Federal Energy Regulatory Commission (FERC) issued a final rulemaking on standard interconnection agreements and procedures for large generators (FERC Order RM02-1-000), and a proposed rulemakings for small generator interconnection agreements and procedures (FERC Order RM02-12-000). *See,* http://www.newrules.org/electricity/interconnect.html.

[150] Arthur D. Little, Inc. at 14.

[151] NARUC, *Model Distributed Generation Interconnect Procedures* at 1-11. *See also*, Ohio State University, *Model DG Interconnection Procedures*.

[152] Interconnection and parallel operation distributed generation agreements are short and range from six to ten pages in length.

[153] IEA, DG IN LIBERALIZED MARKETS at 75.

Treatment of DG in a liberalized wholesale electricity market is not much different than under a regulated monopoly.[154] In Texas, for example, owners of DG can sell electricity to the utility at wholesale, but not to other end-users. The price for power is determined through a negotiated contract.[155] Electricity market liberalization exposes generators and consumers to variable electricity prices and generally encourages more economically efficient generation. In developed countries, this is normally due to "short construction lead times, low capital costs, flexibility in operation and ability to expand output."[156]

Nevertheless, wholesale liberalization by itself does not ensure that DG receives non-discriminatory access.[157] In his article, *Electricity Sector Reform in Developing Countries: Implications for Renewable Energy*, Dr. Keith Kozloff, formerly of Hagler-Bailly (now PA Consulting) notes that: "Compared with long-term power purchase agreements based on full costs incurred over a project's life, spot generation markets weaken the incentive to invest in distributed renewables whose costs must be covered over a period of several years."[158] In many developing countries increased privatization and liberalization of the electricity market has resulted in shorter power contracts, increased borrowing costs and the need to obtain higher rates of return.[159] A recent report released by the New England Demand Response Initiative concludes that "significant market barriers to cost-effective *active load management* [which includes the use of distributed generation] and *energy efficiency investments* will remain, even in conditions of active wholesale competition."[160]

Government intervention is needed to ensure that rules and procedures provide DG fair and non-discriminatory access to the distribution system and improve the ability to compete in the wholesale market for energy, reserve or ancillary services.[161] Wholesale market trading rules also should be designed to facilitate greater participation by smaller generators in such markets.[162] DG proponents also argue that in order for them to be economically efficient, retail markets should be liberalized to allow DG energy producers and customers "direct access" (also known as "retail wheeling" or "customer choice") through the distribution system.[163]

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[154] *Id.* at 78.
[155] NARUC, *Review of Utility Interconnection Tariff and Contract Provisions* at 4-2.
[156] IEA, DG IN LIBERALIZED MARKETS at 76 and 82.
[157] *Id.* at 77-78.
[158] Kozloff, *Electricity Sector Reform in Developing Countries* at 8.
[159] Nilsson, L. J., *Public Benefits In Power Sector Reform* at 6. *See also,* Nilsson, L. J., et. al., *Public Benefit and Power Sector Reform* at 12-13.
[160] New England Demand Response Initiative, *Dimensions of Demand Response* at 2. *See also,* Weston, F., *State Electricity Regulatory Policy* and Moskovits, D. at 1. The report notes that: "Although competition was supposed to open markets and opportunities for distributed resources, form the perspective of these resources, power sector restructuring has been more like sector *destructuring*. Breaking the industry into separate entities subject to different jurisdictions has made it harder for distributed resource vendors and users to see the full value of distributed resources." *Id.*
[161] IEA, DG IN LIBERALIZED MARKETS at 105-107. An important consideration for regulators in a debundled electricity market (where generation, transmission, distribution and retail services are separated), is whether to allow distribution companies to own and operate distributed generation facilities (thereby becoming a power generator). Distribution companies in the U.S., for example, are experimenting with using distributed generation to provide ancillary services. Proponents argue that distribution companies are the best suited to identify where distributed generation can be used to the benefit of the customer and the distribution network. Others fear that allowing distribution companies to be allowed to have ownership of distributed generation might give them additional market powers and access to customers. One option is to allow distribution companies the right to solicit bids for distributed generation within its system. Arthur D. Little, Inc. at 8-9.
[162] IEA, DG IN LIBERALIZED MARKETS at 105-107.
[163] *Id.* at 77 and 102. *See also,* http://www.brooksassoc.com/rates.html.

Under direct access or retail wheeling, electricity that is owned by a power supplier (DG or otherwise) is sold to a retail consumer over transmission and distribution lines owned by a third party. A wheeling fee is charged by the owners of the lines for the use of the transmission and distribution system. A special committee on distributive generation in India recommends that wheeling prices "should be related to reasonable levels of transmission and distribution losses of the State Electricity Boards" while ensuring that the Boards do not incur financial losses. Direct access provides consumers with additional power supply options and creates more competition for power producers.

Given that market liberalization in most developing countries is still in its early stages, DG grid access will likely operate in a more regulated context, at first through contracts with the utility or distribution company (see "Net Metering" below). Governments should facilitate DG power generation by industrial users, particularly the use of combined heat and power, and where possible the sale of excess power back to the grid during peak periods. DG growth in remote areas, through the establishment of micro-grids and home systems, also has tremendous potential. Gradually, as developing country electricity markets become more competitive and sustainable, DG can be allowed to compete with electric utilities in wholesale and perhaps eventually in retail markets. With greater market access, however, also comes increased structural, operational and price complexities that will have to be managed by independent regulators.[164]

4.5 Net Metering

One policy mechanism for promoting small distributed generation is the use of "net metering," sometimes called "net billing." Originally developed for a vertically integrated utility, net metering allows customers to sell electricity from small distributed generation to the local distribution company at (or close to) the retail price.[165] New, more sophisticated metering technologies are capable of tracking usage and sales by time of day. A total of 30 states in the U.S. have adopted net metering for electric utilities in various forms. Net metering prices can vary by customer class (commercial, residential, etc.), size (systems up to 10 or 100 kW), system or fuel type (renewables, cogeneration, including fuel cells) and be limited by a maximum size allowed, or number of customers per geographic area.[166] For example, net metering is sometimes limited to only the electricity sold back to the distribution system that exceeds the amount of electricity consumed by the customer in a given billing period (often called "net excess generation"). The sale of electricity back to the grid is often at retail prices.

But net metering has its limitations. In India, state electricity boards that are required to buy back electricity from biomass and wind power projects at a fixed rate complain that prices they are required to pay are eroding their profitability.[167] The IEA has concluded that it is not economically efficient and has the potential to distort markets.[168] Texas, which allows excess power from distributed generation to be sold into competitive markets, determined that "net metering was not compatible with open retail competition."[169] A report prepared by the Embedded Generation Working Group in the UK, found that a detailed cost-benefit analysis was needed before setting net metering tariffs.[170]

[164] IEA, DG IN LIBERALIZED MARKETS at 76.
[165] See, NARUC, *Review of Utility Interconnection Tariff and Contract Provisions* at 4-10 and 5-2.
[166] *Id.* at 4-11.
[167] Govt. of India, *Report of the Committee on DG* at 56.
[168] IEA, DG IN LIBERALIZED MARKETS at 86-87.
[169] NARUC, *Review of Utility Interconnection Tariff and Contract Provisions* at 4-11.
[170] IEA, DG IN LIBERALIZED MARKETS at 87.

4.6 Electricity Pricing

Another barrier to distributed generation is the utility tariff rate.[171] With interconnection standards and expedited interconnect procedures for DG in place, developing country governments will need to adopt appropriate market signals to take into account the complete range of benefits provided by distributed generation. While DG should be allowed to fairly compete with central power, it must also bear its fair share of the costs imposed on the transmission and distribution system.[172] A number of different factors need to be taken into account when developing an appropriate tariff and fees system for distributed generation.

In many instances DG can bring down the cost of electricity when one takes into account true delivery costs and line losses. The World Alliance for Decentralized Energy (WADE) argues that the standard metrics used to determine the cost of electricity – capital per kW of new electricity generation and cost per kWh to generate electricity – do not capture all the costs, especially the transmission and distribution costs, of delivering a kWh of electricity. [173] A study commissioned by the National Association of Regulatory Utility Commissioners in the U.S. found that most utilities agreed that the expanded use of DG can help reduce energy costs.[174] The potential for similar cost savings exist in developing countries as well.

According to WADE, the following pricing principles should be followed:

1. Electricity system pricing should be fully cost-reflective, with no cross subsidies from one part of the system to another.
2. Use of transmission and distribution networks should be priced according to the services they provide.
3. Any benefits that generators (including decentralized energy) provide to the system (for example, voltage support, grid stability, and reduction in transmission and distribution losses), should be fairly reflected in system pricing.
4. Generators should be charged fees in a fair and transparent way for their system impacts and no more.[175]

The low electricity tariffs and price subsidies in developing countries are among the biggest hurdles that DG will have to face. Presently, privatization in many developing countries has been put on hold and government owned electric utilities remain in dire financial difficulty, while those that have been privatized struggle to survive. A book recently published by the Inter-American Development Bank on power sector reform in Latin America found that while some improvements have resulted from market reforms, the electricity sector is "still plagued by low efficiency, cross subsidies, insufficient tariffs to cover costs, and poor prospects for new investment."[176] Until such time as regulators are capable of imposing and collecting tariffs to cover the costs of the electric utility system, the sale of DG through the electricity grid will likely be minimal.

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[171] NREL, *Making Connections* at 36.
[172] Arthur D. Little, Inc. at 14.
[173] WADE, *Future of Environmentally Responsible Energy Systems*.
[174] NARUC, *Review of Utility Interconnection Tariff and Contract Provisions* at 4-8.
[175] Brown, M., *A New Blueprint for Decentralized Energy* at iii-v. While there is general consensus that distributed generation can provide "grid-side" benefits, there is disagreement over the economic value that such benefits provide. *See*, Arthur D. Little, Inc. at 7.
[176] Von der Fehr, *Power Sector Reform* at 335. *See also*, Powell, S.

Box 4. *Latin America Power Sector Reform: Lessons Learned*[177]

Introducing more realistic price signals is a difficult but key challenge for the power sectors of Colombia, Guatemala and Honduras. Without such signals, new investment cannot be financed, supply capacity will be exhausted, and the power sector will continue to drain government finances. Political support must be mustered to allow for price adjustments. A starting point might be to eliminate certain cross subsidies, especially those that reach middle- or higher-income groups. Measures to increase price flexibility should be targeted primarily at larger customers that will probably be willing and able to negotiate prices on reasonable terms. Eventually, greater use of the pricing instrument should be allowed across all market segments.

Location Based Pricing

Rate structures do not normally take into account the varying costs of providing distribution services.[178] The IEA recommends that location-based pricing mechanisms be adopted to provide incentives to establish DG units along the distribution system where they can reduce overall costs and line losses and relieve congestion.[179] The less electricity delivered the fewer earnings for distributors.[180] The key is ensuring that there is also an incentive for distributors.

Allocating the economic benefits and costs of DG requires reliable data on the generation, transmission and distribution systems.[181] One place to start is by requiring utilities to undertake a cost-benefit analysis of their distribution facilities to assess areas where the local benefits of DG might exceed the costs of upgrading or constructing new distribution lines.[182] In New South Wales, Australia, for example, regulators require the distribution utility to maintain a list of all major distribution upgrades, areas with the worst reliability records and the load reductions needed to avoid upgrades. If poor performing areas are not due to be upgraded, they are candidates for distributed generation. Another location-based pricing mechanism is the use of financial credits for DG installed in a designated area of the distribution grid where upgrades are needed.[183] The credit is a function of the cost savings and is limited in duration and amount. A three-step pilot program for implementing distribution credits has been prepared by NREL.[184] Distribution companies could also be allowed to solicit bids for DG services within the system and award a capacity contract to the bid that proves to be more economical than line required upgrades.[185]

Peak Pricing

Exposing customers to higher costs during peak periods is another means of encouraging the development of DG or reducing demand when the network is most overloaded. This, coupled with special peak tariffs to promote the sale of DG power back into the grid, can also relieve

[177] Von der Fehr, *Power Sector Reform* at 351.
[178] Arthur D. Little, Inc. at 9.
[179] IEA, DG IN LIBERALIZED MARKETS at 105-107. "When transmission pricing does not vary by location (so called 'postage-stamp'), there is no incentive to locate new generating capacity to relieve congestion." *Id.* at 80. The IEA notes, however, that location based pricing systems are both complex and costly. *Id.* at 87.
[180] IEA, DG IN LIBERALIZED MARKETS at 85.
[181] *See,* Shirley, W., *Distribution System Cost Methodologies for Distributed Generation*.
[182] Brown, M., *A New Blueprint for Decentralized Energy* at iv. *See also,* Moskovits, D. at 5-8.
[183] Moskovits, D. at 5.
[184] *Id.*
[185] Arthur D. Little, Inc. at 9.

congestion.[186] Similarly, congestion pricing where load customers pay a tariff for distribution services, can also be used, although it is more difficult to implement.[187]

4.7 Connection and Standby Charges

An important question facing DG is how to fairly charge for the use of the distribution system. Connection charges often serve as a barrier to distributed generation. In the UK, DG generators pay an up-front fee for the cost of connecting to the grid – often called a "deep" connection charge. The fee takes into consideration location-based pricing and obviates the need for any additional distribution fees. The Netherlands, on the other hand, charges DG only for the direct costs of connecting to the grid. Larger distributed generation is also assessed an additional systems fee. The IEA recommends the use of a direct connection charge for new distributed generation connected to the grid and allowing distribution companies to issue fees to recover any grid reinforcement costs that result from DG providers.[188]

In the U.S., many utilities apply what are known as "standby charges" to DG facilities. These are usually a monthly demand charge ($/kW) that is associated with the fixed cost of the transmission and distribution system.[189] Standby charges also serve to compensate the utility for the supply of electricity to replace or supplement a customer's usual source of DG power or to provide backup during unscheduled outages. Many utilities complain that the standby charges are too low. Critics counter, however, that the fees imposed by utilities are excessive and based on worst-case scenarios. The true cost of providing standby power is difficult to assess on a customer-by-customer basis.[190] Nevertheless, it is a matter that must be addressed in a balanced and equitable manner.

Another issue is whether utilities should be compensated for "stranded costs" – costs for previous generation, transmission and distribution investments that are not needed because customers are self-generating with DG. Utilities seek to recoup these costs by imposing "competitive transition charges" (CTC). When customers leave the grid or reduce their loads through the use of distributed generation, utilities will often charge an "exit fees" to make up for the lost sales.[191] Normally state restructuring laws or the state public utility commission set the CTC or "exit fee." Such fees are often based on a customer's historical load usage. They can either be issued in a one-time lump sum payment or paid over time.[192] Utilities contend that customer's who install DG unfairly shift the burden of paying for "stranded costs" on other utility customers, who must make up the loss by paying higher fees.

[186] IEA, DG IN LIBERALIZED MARKETS at 86.
[187] Another advanced tool is "demand response," that is, active load management by customers to enhance market efficiency and system reliability coupled with energy efficiency investments to lower "market clearing prices," improve reliability and lower overall costs. Like congestion pricing, however, demand response requires real-time market information, something developing countries almost never have. *See*, New England Demand Response Initiative, *Dimensions of Demand Response* at 2. For a discussion of technical factors influencing demand side management service pricing strategies, see California Energy Comm., *Distributed Generation Case Studies* at 177.
[188] See, IEA, DG IN LIBERALIZED MARKETS at 83-84.
[189] Arthur D. Little, Inc. at 18.
[190] *Id.* at 19-20.
[191] See, NARUC, *Review of Utility Interconnection Tariff and Contract Provisions* at 4-9.
[192] *See*, the Energy and Environmental Analysis, Inc. web site http://www.eea-inc.com for a state by state review of "exit fee" requirement and other DG issues in the U.S.

These fees, however, can have a significant effect on the economic viability of a DG project. Critics argue that such fees act to limit market competition from more efficient and cost-effective DG sources. Opponents also add that the amount of DG installed will not outpace demand growth.[193] A number of states in the U.S. have exempted distributed generation from paying for stranded costs. New Jersey and Massachusetts, for example, impose a fee to recoup stranded costs from DG only after it reaches a certain level of market penetration.[194] The market penetration level for New Jersey is 7.5 percent and 10 percent for Massachusetts.[195]

4.8 Codes, Permits & Environmental Standards

Another potential obstacle to DG is navigating the bureaucracies of city and local agencies associated with zoning, siting and environmental impact matters. The adoption of DG technologies often will require complying with a plethora of local building, fire, health and safety requirements, waste management and storm water discharge standards.[196] The time and cost associated with obtaining such permits can be daunting. To the extent such permitting requirements exist, local agencies should develop handbooks for preparing the required paper.[197] Energy regulators can also assist distribution companies by providing them with guidance on the level of review expected for different technologies; lists of the local agencies responsible for approving DG projects; and samples of DG projects that have previously received agency approval. Checklists with the possible environmental impacts from DG projects, and summaries of the compatibility of such projects with local land use plans and ordinances, should also be explored. In each instance, application review and approval processes should be expedited.

Streamlining may be required with air permits, which in the US have been cited as one of the obstacles to distributed generation.[198] Many developing countries, however, may not even have such regulations in place. Most air emissions standards are designed with large central power stations in mind and based on "emission per unit of fuel consumed" and not "emissions per unit of power produced," or in the case of combined heat and power, "kilowatt-hours and equivalent energy produced." [199] Setting emissions standards on unit of fuel consumed discourages energy efficiency and pollution prevention. Recommendations for improving environmental requirements for distributed generation include:

- Creating a streamlined and uniform standards approach to distributed generation projects, with "pre-certification" and minimum requirements that balance economic considerations with public policy objectives;
- Allowing the replacement of older technologies with new DG technologies;
- Issuing credits for cogeneration operations; and
- Providing emissions allowances for renewables or other environmentally beneficial DG technologies.[200]

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193 Arthur D. Little, Inc. at 16-17.
194 This is determined by a percentage reduction in kilowatt hours distributed.
195 See, Arthur D. Little, Inc. at 17 and NARUC, *Review of Utility Interconnection Tariff and Contract Provisions* at 4-9 and 4-10.
196 California Energy Comm., *Distributed Generation Case Studies* at 81-92.
197 *Id.* at 108-110.
198 U.S. Department of Energy, *Cleaning the Air: A Review of the Environmental Permitting Barriers to DER*.
199 See, Arthur D. Little, Inc. at 22
200 *Id*. at 23. *See also,* IEA, DG IN LIBERALIZED MARKETS at 105-107. Recommendations on ways to streamline the air permitting process for distributed generation is also addressed in, The California Energy

The development of new environmental permitting requirements should still allow localities to maintain permit jurisdiction to "insure that all high-priority public policy interests are protected, if not advanced."[201]

5. Economic and Financial Incentives

While establishing a favorable regulatory environment is important, additional financial incentives are also required to address DG's high up-front costs. A number of financing mechanisms can be considered for DG, including tax incentives, buy-down programs, special tariffs, low interest loans and guarantees and development funds. Box 5 outlines the critical elements needed in developing a successful financial incentive program. The appropriate mix of financing options will depend largely on whether the market is at an advanced, emerging or initial pioneer state, the strength of the country's finance sector and the anticipated demand for the technology.[202] In devising an incentive scheme, governments need to evaluate and assess the actual status, benefits and limitations of current and future DG technologies.[203] Studies have shown that multiple financial incentives are necessary to advance distributed generation markets, particularly for renewable technologies. Ultimately, financial incentives should form part of a larger infrastructure and energy development strategy that is market driven.

5.1 Tax Incentives and Credits

Tax incentives are an important tool in promoting DG. These include income tax, investment tax and production-tax credits, tax loss carry-forwards, capital depreciation, duty exemption on imported capital equipment and tax credits on domestic equipment.[204] If successful in expanding markets, tax credits can end up providing a net gain in revenues to the taxing entity.[205] Most modern DG technologies in developing countries will have to be imported at first. Some larger countries, such as Brazil, India or Mexico, manufacture their own DG technologies. In India, the use of investment tax credits and the relaxation of import tariffs were vital in helping to stimulate the country's wind and solar PV market.[206]

Exemptions for sales and property taxes and the reduction or elimination of customs duties on imported equipment offer important investment incentives. Income tax credits that reduce an individual's or business' federal or state income tax, normally for 10 to 35 percent of the investment, may also be used to allow either accelerated principal and interest payments or a higher rate of return.[207] A recent report for NREL on the effectiveness of state incentives in the U.S. for renewable energy found that investment tax credits are simpler to administer and enforce compared with other incentives.[208] They may also be more politically palatable than cash payments because

Comm., *Workshop Report on Distributed Generation CEQA and Permit Streamlining*. Model air regulations for distributed generation have also been developed by The Regulatory Assistance Project. *See*, Regulatory Assistance Project, *Model Regulations*.

[201] Arthur D. Little, Inc. at 23-24.

[202] Nordströ̈m, S., *Establishing a Network of Solar Photovoltaic (PV) Programmes* at 3.

[203] Arthur D. Little, Inc. at 25.

[204] ARMSTRONG, A. J., RE POLICY MANUAL at 89-91.

[205] Gouchoe, S., *Financial Incentives for Renewable Energy* at 7.

[206] Martinot, E., *Government Policies and Private Finance* at 47.

[207] See, ARMSTRONG, A. J., RE POLICY MANUAL at 89-91 and Gouchoe, S., *Financial Incentives for Renewable Energy* at 7-11.

[208] Gouchoe, S., *Financial Incentives for Renewable Energy* at 7.

Box 5. *Critical Elements for a Successful Financial Incentive Program*[209]

1. **Funding Stability and Duration**. Incentives should be available over multiyear terms and have stable funding.
2. **Incentive Amount**. First, the incentive level must be high enough – particularly in the first years of the program – but not so high that it distorts the market sector it is intended to help. Second, the incentive amount should decline over time as the market develops. This acts to motivate potential customers to buy sooner when the incentive is higher and to help wean the industry and the marketplace off the incentive, easing the transition to a subsidy-free sustainable market. Finally, incentives should be limited to a certain level-per-watt capacity to prevent manufacturers and dealers from inflating prices.
3. **Quality Assurance**. Incentive programs must include provisions to ensure adequate system performance through minimum equipment standards, installer certification, and production-based incentives.
4. **Application Process**. Incentives should be easy to apply for and include appropriate assistance from program administrators. Early adopters who experience a cumbersome application process accompanied by a long wait to receive an incentive payment (a buy-down) or approval for loan, are likely to spread the word to others, deterring potential customers from using the program.
5. **Consumer Education and Awareness**. A sustained marketing campaign to educate the public about DG technologies in general, and about the availability of incentives in particular, is critical to program success.
6. **Institutional Barriers**. Program success will be limited if institutional and structural issues are not addressed. These include working with utilities to develop a smooth and standardized interconnection process, and educating the inspectors, realtors, insurers, bankers, utilities, and other stakeholders who may participate in or have authority over deploying the technologies.
7. **Complementary Financial Incentives**. Any given incentive should be considered as part of a package of policies designed to stimulate market development. Financial incentives that can complement or enhance tax credits and buy-downs include low-interest loans, net metering, property tax exemptions, and sales-tax exemptions.

they do not require governments to appropriate funds. Maximum limits range from $1,000 to $10,500 for residential and up $50,000 or more for commercial systems. According to NREL, carrying-over tax credits should be limited to avoid reducing the tax's overall benefit.[210] Governments may also want to consider including performance requirements as part of a tax credit plan to ensure that DG systems are not only built but actually produce power.

Another tool is the production tax credit where credit is issued based on total kilowatt-hours of electricity produced. Credits may be applied to the purchaser or distributor of electricity from a DG facility. Production tax credits are more difficult to apply for smaller scale systems, especially those located off-grid. Nevertheless, according to the review by the World Bank of Global Environment Facility projects designed to remove barriers to renewable energy in developing countries, "[p]olicies that promote production-based incentives rather than investment-based incentives are more likely to spur the best industry performance and sustainability."[211]

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[209] Gouchoe, S., *Financial Incentives for Renewable Energy* at 3-4.
[210] *Id*.
[211] World Bank, *Mexico-Large-scale Renewable Energy Development Project* at 11-12. The project proposal cites the case of India in the early 1990's, where a 100 percent investment tax depreciation helped stimulate nearly 1,200 MW of wind capacity by the private sector. However, the depreciation was abused by companies that were more interested in the deduction that actually implementing projects. As a result a

One potential drawback to tax credits or exemptions is that they normally only apply to entities that pay taxes. The impact can also be muted if collection rates are low due to tax evasion, which is a serious problem in many developing countries. Tax credits also leave out important market players, such as charities, NGOs and government entities. To address this issue the state of Oregon established a "pass-through" option where a tax-exempt entity is allowed to transfer the tax credit to a third party in exchange for the net value of the credit.[212] Another important element to consider when adopting tax incentives is which agency will be responsible for its implementation. Will it be the revenue department or the energy ministry? The latter will allow for better control of program details, such as the number of participants and types of technologies installed.

5.2 Buy-Down Programs

Another tool available to governments is the use of "buy-down" programs that offer rebates or cash incentives to encourage the installation of DG technologies. The theory behind "buy-down" programs is that they stimulate early technology deployment and encourage manufacturers and distributors to increase their investment.[213] Incentives often range from $3/W to $6/W (20 to 60 percent of the system cost) and include a performance standard to ensure that the operation is completed.[214] Studies suggest that high and sustainable incentive levels are required in the early stages of a program until barriers are eliminated and the market matures.[215]

While consumers generally prefer cash incentives to tax credits, they require explicit funding and can cause problems if the industry grows too rapidly. Care must be taken to ensure that demand does not exceed the capacity of equipment suppliers and qualified installers. The discontinuation of programs can also have a sudden adverse impact on the industry. Governments may also need to help ensure that infrastructure needs are met. In some instances, utilities may be provided grants to assist in developing distributed generation technologies in their service areas.

5.3 Low Interest Loans, Credit and Guarantees

Another barrier to DG technologies, particularly renewables, is attracting access to long-term credit on reasonable terms. Rural customers and clean energy entrepreneurs that service them find obtaining credit particular difficult.[216] Long-term loans at low interest rates are an important vehicle for addressing the high up-front capital costs of DG technologies. Financing can either be provided to the consumer through end-user credit mechanisms, to the utility, to the DG company or energy service provider, or to other financiers, including micro-credit institutions and NGOs.

Banks in Indonesia provide low-interest loans to consumers to purchase home PV systems, and NGOs in Peru and Nepal are making credit available to local communities to install micro-grid systems that use small hydroelectric systems.[217] Energy service companies provide end users credit through fee-for-service PV or wind electrification, where the customer pays a monthly or quarterly

number of the turbines built are now inoperative. *Id. See also,* Govt. of India, *Report of the Committee on DG* at 53.

212 Gouchoe, S., *Financial Incentives for Renewable Energy* at 7.

213 *Id*. at 11.

214 For more information on U.S. state incentives for distributed generation technologies, consult http://www.dsireusa.org. The web page has a complete database of state financial and economic incentives with summaries and links to individual state web sites.

215 Gouchoe, S., *Financial Incentives for Renewable Energy* at 25-27.

216 See, Císcar, J.C..

217 Barnes, D., *Tackling the Rural Energy Problem in Developing Countries* at 6.

fee for the electricity produced.[218]

If implemented properly, loan programs can be self-sustaining through a revolving fund and be tailored to achieve different goals. By themselves, however, low interest loans often do not provide enough cost savings to spur significant market development. Issuing below market rates and keeping fees to a minimum will help ensure greater program success.[219] Like buy-down programs, funding could be derived from a specific source, either through a system-benefit charge, special taxes (such as on petroleum), the sale of bonds, or annual appropriations from government revenues. Another important vehicle when selling power to a government controlled entity is the receipt of a "performance undertaking," or guarantee by the government, that ensures the entity will discharge its obligations.[220] Such a guarantee is often required by international or multilateral finance agencies, particularly for larger projects. Counter guarantees may also be required to back up local government guarantees on debt that is locally raised.[221]

5.4 Public Benefit Funds for Rural Electrification

A major benefit of distributed generation is its ability to be located in remote areas where grid extension is not economically or physically viable. There are three types of rural populations that are traditionally served by distributed generation: *dispersed families* (people that are located too far from other population centers to be served by the grid); *population centers* (people living close enough to share energy resources, usually ten to 500 households living in villages); and *isolated production centers* (commercial facilities that usually have their own generation facility).[222]

Traditionally, state-owned utilities were encouraged to expand their grids to rural areas regardless of cost. Such projects were often overbuilt and exceeded customer demand. Because transmission and distribution costs are often high for remote areas, developing country electricity rates in rural areas are frequently subsidized. With the unbundling and privatization of electric utilities, distribution companies are more focused on raising revenue to cover costs and have little appetite for extending grid services unless forced to do so or sufficient incentives are provided. A report by the Special Committee on Distributive Generation in India found that "State Governments have been reluctant to avail themselves even of the assistance of the 100% grant under the Kutir Jyoti programs on account of apprehension due to recurring revenue loss through such concessions."[223]

In most instances government subsidies are required to accelerate rural electrification. Appendix 1 outlines the World Bank's views on good and bad subsidies. The first rule of thumb is that subsidies should always fall within the government's own financial and human resource constraints. Second, subsidies should only be directed at lowering the cost of capital and reducing the cost of energy, and not be used to cover operating expenses.[224] Subsidies and grants may also be needed for "market-conditioning activities" such as preparing resource and feasibility studies, project design, promotion and training, and setting and enforcing standards.[225] There are a number of different models for providing government subsidies for rural electrification. Argentina has adopted a top-down approach, giving a monopoly to the company that offers the greatest amount of service

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218 UNEP, *Open For Business* at 7.
219 Gouchoe, S., *Financial Incentives for Renewable Energy* at 14.
220 ARMSTRONG, A. J., RE POLICY MANUAL at 90.
221 *Id*. at 106.
222 ARMSTRONG, A. J., RE POLICY MANUAL at 98-99.
223 Govt. of India, *Report of the Committee on DG* at 42.
224 Subsidizing operating costs usually undermine the government's financial position.
225 Císcar, J.C.; *see also,* A. Cabraal, *Best Practices for Photovoltaic Household Electrification Programs*.

Box 6. *Case Study: Chile's Rural Electrification Program*[226]

Although Chile liberalized its electricity sector in the 1980s with considerable success, market reforms failed to meet rural demand. By the early 1990s, half of the country's rural population – a million people – still lacked electricity. In 1994, Chile launched an ambitious rural electrification program that used a competitive, least-cost bottom-up approach that included state subsidies, regional and project competition for funds, private sector energy services, social and economic indicators and a decentralized and fully transparent decision making process.

At the state level, the National Energy Commission (CNE) manages the program and provides a one-time direct subsidy to private distribution or energy service companies to cover their investment costs. CNE allocates the subsidy funds to regional governments based on the amount of progress made in the previous year and the number of remaining households without electrification. The CNE also provides regional governments with planning and management models, methodologies for ensuring efficient allocation of state subsidies and pre-investment studies to establish sound project portfolios.

Normally, communities seeking rural electrification projects do so with the support of local distribution or energy service companies. Most projects involve line extensions but also include renewable and hybrid off-grid applications. Proposals are presented to the municipal government that in turn asks the private company to prepare a technical project. Once complete, all technical proposals are listed in a public registry. Users must cover the costs of wiring and the metering and coupling to the grid, which usually amount to 10 percent of the project's costs. These costs are advanced by the distribution company and paid by the users over time, on top of the regulated tariffs. Private companies invest their own resources, own and manage the installations and assume the commercial risk.

Projects are evaluated by the regional planning agency and include their social impact, cost-benefit ratio and the amount of private investment being offered providing for the highest impact per unit of investment. In order to receive a subsidy, a project must have a positive social but negative private rate of return. The program allows companies to obtain a 10 percent return on investment over a 30 year period. Those that meet the minimum requirements are then reviewed by the regional council that manages the subsidy and approves the final projects. Off-grid projects normally involve one-house photovoltaic systems, of which 1,000 have thus far been installed. Occasionally, grants are also dispersed for off-grid projects.

In seven years, the program increased Chile's electrification rate 53 percent in 1995 to 75 percent in 1999. The average state subsidy increased by $430 from $1,080 in 1995 to $1,510 in 1999 per household. Responding to a request from the government of Chile, the Inter-American Development Bank in September, 2003, approved a US$40 million loan to reach 90 percent in every Chilean region by 2006. This new phase of the Chilean Rural Electrification Program will provide grid access to 28,000 new families, as well as sustainable off-grid solutions to 8,000 families, based on single home solar photovoltaic systems and isolated mini grids supplied by wind-diesel hybrid or small hydropower generation systems.

at the lowest price.[227] Giving exclusive access to one provider or distribution company has a number of benefits. As Keith Kozloff, formerly with PA Consulting, notes, a distribution company with exclusive access to an off-grid area can "balance returns of grid-connected and off-grid customers, . . . absorb market entry costs, achieve economy of scale in equipment and operations and maintenance costs, exploit its existing network of local agents, and use its large cash flow to finance systems and absorb seasonal variations in customers' ability to pay."[228]

In Chile, the government adopted a slightly different approach than Argentina. (See Box 6 above). Chile's rural electrification program is a more bottom-up approach that requires private developers and regional governments to compete for federal funds and provides a market incentive that encourages the adoption of least-cost options that also provide the greatest benefit to the public.

[226] Jadresic, Alejandro, *Promoting Private Investment in Rural Electrification* and interview with Arnaldo Vieira De Carvalho with the IADB.
[227] ARMSTRONG, A. J., RE POLICY MANUAL at 105.
[228] Kozloff, *Electricity Sector Reform in Developing Countries*.

Appendix 1 outlines some of the lessons learned by the World Bank in undertaking rural electrification.

While most rural electrification projects involve grid extensions, the more remote projects are increasingly turning to renewable DG sources. According to Anil Cabraal with the World Bank Energy and Water Department, "countries are beginning to recognize off-grid options as a legitimate electrification method."[229] Understanding local needs is vital for the successful application of DG technologies in remote areas. Local community organizations, rural cooperatives and NGOs can assist with needs assessment and project implementation. Combining decentralized energy projects with other infrastructure projects, such as those extending water, health, educational, and telecommunications services, can also engender community support and help leverage funds from different sources.[230] Still, even with subsidies, credit and other finance assistance, more is often needed to deepen market penetration.

6. Investing in Human Capital, Education and Outreach

For distributed generation to gain market entry in developing country electricity markets, government commitment will be needed on many fronts. Particularly important is the need for adequate delivery mechanisms. Over the past ten years, a large number of DG pilot projects in developing countries have failed, largely due to lack of maintenance and incorrect use.[231] In Senegal, nearly 90 percent of the country's wind-powered water pumps are inoperative due to lapses in maintenance.[232]

For DG technologies to succeed requires sufficient human capital to install and repair them. Developing countries have a large labor supply that can easily be trained to assemble, deploy and service small DG energy systems. Government can help by providing training for contractors and institutional support and technical assistance to businesses and small entrepreneurs working in DG services. Development funds can also be used to provide small grants and seed capital for start-up companies that provide DG services, particularly those working in rural areas.[233] In addition, greater understanding of DG technologies by end users is vital. As R.K. Pachauri, former President of the Tata Energy and Resources Institute-North America, notes, "capacity must be built within the user base to perpetuate usage."[234]

Greater understanding of DG technologies is also very important. As part of their overall development strategy, governments will need to engage and educate a variety of players about different DG technologies, their benefits and the availability of financial incentives and other sources of support. Government outreach should also include the general public, industry, regulators, inspectors, realtors, insurers, bankers, utilities, distribution companies and other

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[229] Cabraal, A., *Decentralized Electrification Experiences and Lessons Learned.*
[230] ARMSTRONG, A. J., RE POLICY MANUAL at 107.
[231] Císcar, J.C. at 4.
[232] UNEP, *Open for Business* at 6.
[233] *See,* UNEP, *Open for Business*. The United Nations Environmental Program and the United Nations Foundation are working with E+Co to establish a new rural energy enterprise development (REED) model for the delivery of renewable energy and energy efficiency services to rural and peri-urban areas in developing countries. REED helps entrepreneurs develop clean energy business proposals and plans, assess market conditions and provide seed capital and management support and raise second stage financing. *Id.* at 13. A REED toolkit on writing a business plan, fact-finding, feasibility analysis and composing the business plan is available in English, Portuguese and French on AREED's web site at: http://www.AREED.org/training.
[234] Pachauri, at 18.

stakeholders.[235]

7. Conclusion

Although distributed generation is not a panacea for solving developing country energy problems, when combined with energy efficiency measures it has considerable potential to help meet increased electricity needs. Distributed generation can lesson demand and reduce peak loads, postpone the need for expensive line upgrades, add much needed power to the grid through greater use of combined heat and power and other DG technologies, extend power to remote areas and create income through the sale of excess power back to the grid. It also offers important environmental benefits. DG technologies have the potential to reduce air emissions and improve public health. They also emit less greenhouse gasses than the traditional energy mix.

Still, challenges to DG technologies abound. Most developing country electricity markets suffer from a lack of competition and weak regulatory bodies. Continued use of subsidies undermines the financial stability of many utilities and discourages the use of distributed generation by hiding the true cost of providing electric power to the consumer. Promoting DG technologies requires new investment, sufficient equipment and skilled technicians. It also involves a high degree of regulatory complexity and government involvement, which seems difficult at a time when several studies point to the need for developing countries to simplify their energy regulations to better reflect local market conditions.[236]

With most power sector reforms in developing countries still a work-in-progress, governments have an opportunity to modify the traditional central power station model and adopt a more flexible regulatory framework that levels the playing field for DG technologies. Recognizing that there are both benefits and costs associated with DG, the first step for governments is to carefully examine the impact and viability of DG under local market conditions and the potential contribution that DG can make to a country's energy mix. Working in close consultation with utilities, transmission companies, energy service companies, regulators, trade associations and NGOs, governments will need to assess:

- existing distributed generation power sources from local industry;
- the potential for greater use of combined heat and power applications;
- the availability of manufacturers, suppliers and distributors of DG technologies;
- the true costs and infrastructure needs of transmission and distribution networks;
- options for DG technologies to meet rural and urban electrification needs without compromising system integrity, reliability or safety;
- the impact of DG on the financial viability of the central electric utility system; and
- specific technical, regulatory, administrative and financial barriers to distributed generation.

From this process should emerge a development plan that clearly identifies ways to accelerate the use of DG technologies in targeted areas to help meet power sector objectives. Key elements of such a plan should include or address the following issues:

[235] Gouchoe, S., *Financial Incentives for Renewable Energy* at 3-4.

[236] See, Von der Fehr, *Power Sector Reform* at 361-367; See also, Kozloff, *Electricity Sector Reform in Developing Countries*.

- **Essential Market Reforms and Conditions.** Even if a vertically integrated electric utility remains intact, private entities should be allowed to generate power, interconnect with the grid and compete in wholesale markets on non-discriminatory terms. Transmission and distribution costs need to be evaluated to help determine the benefits and impacts of DG to the grid and promote least-cost system upgrades and expansion. An independent regulator should be established with the authority and resources necessary to police the market.
- **Uniform Standards & Procedures.** Uniform technical standards for grid interconnection and testing and certification procedures for DG equipment should be made easily accessible. Similarly, grid interconnection and parallel operation applications and power purchase agreements should be streamlined and standardized to lower transaction costs. Dispute resolution procedures should be adopted to ensure fair and speedy resolution by a qualified entity or government body. Equipment installers should be certified to ensure quality system performance and adequate maintenance. Local authorities should be directed to simplify application procedures to comply with fire, health and safety, zoning, environmental impact, water discharge and waste management requirements.
- **Elimination of Cross-Subsidies.** Cross subsidies should be gradually discontinued.
- **Pricing.** The ancillary and environmental benefits of distributed generation should be recognized in any pricing system. Long-term and stable tariffs and power purchase contracts should be provided for DG power producers connected to the grid.
- **Transmission Charges & Fees.** Connection and back-up charges should be limited to a generator's impacts and benefits to the distribution system. Transmission rate structures should not be biased against low-capacity renewable DG technologies.
- **Natural Gas Infrastructure.** Natural gas distribution networks should be strengthened and expanded in industrial and commercial areas that can most benefit from distributed generation.
- **Market-Based Mechanisms.** There should be a thorough exploration of market-based mechanisms, such as emissions or renewable energy credits, and taxes that incorporate environmental costs and more adequately represent energy conversion efficiencies.
- **Economic Incentives.** An economic incentive package to stimulate DG market development should ensure that production actually occurs and incentives do not distort the market. An aggressive marketing and out-reach campaign should be undertaken simultaneously in collaboration with utilities, trade associations, NGOs and local government entities.
- **Rural Electrification.** DG technologies should be allowed to fairly compete with grid extension based on a least cost analysis and an assessment of local electricity needs. Whenever possible, rural electrification should be integrated with other infrastructure development projects.
- **Technical and Institutional Support.** Governments will need to provide a wide range of technical and institutional support to industry and business, utilities, local entrepreneurs and government agencies to facilitate the deployment of DG technologies and services. Wider awareness of both the pros and cons of distributed generation will be needed. Government leadership and commitment is essential.

In the long run, power sector reforms in developing countries that continue to unduly favor conventional centralized power generation technologies will have an increasingly detrimental environmental impact and are likely to fail in meeting the performance, quality and power needs of end users, especially those located outside large cities. With the proper regulatory structures and incentives, DG can complement central power while increasing access to energy in an incremental, clean and reliable manner.

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Appendix 1

World Bank Rural Electrification: Lessons Learned

Project Criteria. Criteria for selection and priority-setting for rural electrification should be open and objective. Political interference in the implementation of rural electrification programs can add considerably to the costs of system expansion.

Local Involvement Key. Rural electrification programs can benefit greatly from the involvement of local communities - or suffer because of its absence. Projects are more likely to be viable and sustainable if local stakeholders are involved in their design and implementation. One way to approach this is to set up a Rural Electrification Committee to help assess level of demand, educate consumers, and promote the wider use of electricity. The concept of "Area Coverage Rural Electrification" – a distribution system based on member-owned rural electric cooperatives - has been successfully used (e.g. in Bangladesh).

Grid Extension. Grid extension is sometimes not the most cost-effective solution; decentralized delivery options and alternative energy sources--such as solar PV, mini-hydro and other renewable energy sources--should be considered, following the principle of least-cost development.

Private Sector Participation. The private sector can be attracted to participate in rural electrification schemes, even in a poor country, if an appropriate legal framework and risk management options are in place, including the assurance of a level playing field in terms of competition and the ability to charge full cost-recovery tariffs.

Financial viability/cost recovery. Identify economic limits to extensions to the grid and the economic potential of lower-cost options and alternative energy sources. A rational system of cost recovery should take into account capital investment costs, level of local contribution, number and density of consumers, likely demand for electricity; also, the willingness to pay and payment capability of the population.

Tariff Regime. The tariff regime should ensure that rural electrification programs are financially sustainable and will not drain operational resources. Tariffs should cover the full cost of medium-voltage generation/transmission, plus low-voltage operations/maintenance costs, and should provide for eventual capital replacement costs.

Connection Charges. Initial connection charges are a greater barrier to rural families than the monthly electricity bill. Consider the provision of financing to spread the costs of connection fees over an extended period, or lower connection rates for the poor, so that the benefits of electrification may reach larger numbers of people; consider also arranging financial assistance for the credit/hire purchase of electrical appliances.

Good Subsidies. The tariff structure needs to ensure that any subsidies are fair, equitable, and sustainable. A "good" subsidy scheme enhances access for the poor (improving the quality of life/reducing energy expense); encourage the rural electrification business; sustains incentives for efficient delivery/consumption; and must be practicable within the financial/human resource constraints of government/power utility. A portion of the capital may be subsidized, obtained at concessionary rates, or as a government/donor grant. A low lifeline tariff is acceptable on income redistribution grounds.

Subsidy No-Nos. Subsidization of operating costs has widely proved to be counter-productive and to undermine the utilities' financial position, their ability to extend service, and ultimately the rural electrification programs themselves.

Implementation agency. Implementing agencies must have a high degree of operating autonomy and be held accountable; dynamic leadership and employees with job security and career prospects are a key to success. Clear contractual arrangements between the government and implementing agencies are important.

Minimize construction and operating costs. Assess technology and available standards during the planning stage; deploy low-cost equipment; use innovative technologies, approaches, and local suppliers; standardize materials. Consider the use of "ready-boards" to reduce connection costs. Design the system for expected loads (much lower in rural than urban areas) to reduce construction costs; provide for future upgrades.

Source: Arun Sanghvi and Douglas Barnes, *Rural Electrification: Lessons Learned*, in AFRICA REGION FINDINGS (No. 177 February 2001).

Appendix 2

California Energy Commission - Key Policy and Regulatory Questions for Distributed Generation

Interconnect Issues

- Can interconnection rules be standardized?
- Can interconnection be made more user-friendly to the end consumer?
- Can a substantial amount of DG be interconnected in both radial and networked distribution systems?
- Are there safe, reliable and cost-effective interconnection solutions for radial and networked distribution systems?
- Can interconnection solutions be applied in a timely manner?
- Can Engineering studies for interconnection be eliminated, standardized or streamlined?
- Is a single DG unit compatible with end-use equipment or other DG equipment?
- Can qualified interconnection systems be certified so that they may be installed with minimal field-testing?
- Have potential DG installations been postponed or abandoned due to existing interconnection rules or costs?

Grid Effects

- What are the beneficial and detrimental impacts of high DG penetration on the transmission and distribution system, and how may they be quantified and assessed?
- What are the limits to the level of DG that the grid can absorb without adverse consequences?
- What are the limitations on bi-directional power?
- Should the design of new distribution feeders consider DG?
- Are the use of micro-grids practical?

Market Integration and Regulatory Issues

- It is in the State's interest to promote DG?
- How should the rules be modified to allow DG to better participate in current markets?
- Can transaction costs associated with obtaining permits for DG be reduced?
- How can tariffs and rates be designated to provide better price transparency to DG?
- Are there too many public subsidies being provided for DG?
- Should incentives for DG be further enhanced?
- Should regulatory rules be changed to support the development of micro-grids?
- How does the suspension of direct effect impact the marketability of DG?
- Are there ways to balance the imposition of "exit fees" with the marketability of DG?
- Should utilities be offered incentives in return for eliminating exit fees when DG is installed on their systems?
- Should standards for system control and communication devices be developed to better enable DG to participate in markets?
- Should utilities be provided incentives to facilitate DG?
- Should utilities be allowed to install and use DG, and participate with other DG developers, and if so, how should this proceed?

Environmental Issues

- What is the environmental impact of DG technologies, and how can their impact be minimized?
- What is the environmental life-cycle impact of DG compared to central station power plants?
- What technologies and emission controls are needed to make air emissions from DG as clean as those from central station power plants?
- What would be the best way to promote waste-to-energy DG projects that help improve air and water quality and reduce greenhouse gases?

Source: CALIFORNIA ENERGY COMMISSION, DISTRIBUTED GENERATION STRATEGIC PLAN, P700-02-002, 14-16 (June 2002).